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ENVIRONMENTAL SURVEILLANCE
OF SPRAY OPERATIONS FOR
FOREST PROTECTION IN NEW BRUNSWICK
1980-81

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OF SPRAY OPERATIONS FOR
FOREST PROTECTION IN NEW BRUNSWICK, 1980-81

Report by: The New Brunswick Committee for Environmental
Monitoring of Forest Insect Control Operations
(EMOFICO)

Edited by: D.R. Townsend
Washburn & Gillis Associates Ltd.

Editorial Committee: D. Besner, Environment New Brunswick
D.C. Eidt, Canadian Forestry Service
C. MacLaggan, Environment New Brunswick
P.A. Pearce, Canadian Wildlife Service

Published by: Environment New Brunswick
1982

ABSTRACT

Aerial applications of insecticide were used in spruce budworm control operations in New Brunswick, Quebec, Newfoundland, and Maine, and smaller-scale operations in Ontario and Nova Scotia. In the New Brunswick operational spruce budworm control programs in 1980 and 1981, mainly fenitrothion was used. Aminocarb (Matacil^R) was also used in 1980, but on only a small proportion of the forest area treated. Other insecticides were used in experimental spruce budworm control programs in New Brunswick, and in some operational and experimental programs elsewhere. A biological insecticide based on the bacterium Bacillus thuringiensis, and various chemical insecticides including Reldan^R (chlorpyrifos-methyl), Sevin-2-Oil^R (carbaryl) and permethrin were all tested in experimental programs in New Brunswick to determine their efficacy, or environmental impact, or both.

Summarized in this report are aspects of environmental surveillance in New Brunswick in 1980-81 of: wildlife; pollinators; forest arthropods; freshwater fauna; and insecticide analysis, distribution, and persistence and toxicology. Provincial and federal environmental regulations pertaining to insecticide use are also summarized.

Studies of the non-target impacts of fenitrothion revealed effects on songbirds (cholinesterase activity and nestling growth), arboreal predaceous insects (population density), and arboreal spiders (species diversity). No effects on perennial population density trends of arboreal predaceous insects or spiders were evidenced following either fenitrothion or aminocarb spraying. Reductions in the numbers of arboreal arthropods occurred following experimental applications of various formulations of aminocarb. The degree of reduction appeared to depend upon the formulation of aminocarb used. Studies of the impact of aminocarb on forest-dwelling birds, fish in streams, and microbial communities in ponds in New Brunswick revealed no detrimental effects; however, the rate of carbon assimilation by algae in ponds was reduced briefly.

(ii)

The distribution and persistence of insecticides and some of their breakdown products in the air, and in forest, stream and pond ecosystems are described. Fenitrothion rapidly mixed in streams and was distributed to all levels of the water column. The rate of movement of aminocarb in ponds depended upon physical factors such as the wind.

After spray applications, the concentrations of both aminocarb and fenitrothion and some of their breakdown products generally declined rapidly. These compounds persisted at small concentrations for different durations (usually short) in different organisms and parts of the environment; however, instances of fenitrothion persistence at larger concentrations and for longer durations were also reported.

Components of aminocarb and fenitrothion formulations were found to differ in their toxicity to aquatic organisms. Estimates of the toxicity of insecticide formulations, which are typically established on the basis of just the active ingredient portion of the formulation, may therefore be low and safety margins may be narrower for some organisms than was previously thought. A model which facilitates the comparison of the toxicity of pesticides and their various formulations is described.

Characteristics of insecticide drift, its distribution, factors affecting drift, and models used to predict drift behavior are discussed with particular reference to the findings of the New Brunswick Task Force on Drift. Use of buffer zones was found to reduce drift deposit in non-target areas.

Recommendations of the New Brunswick Committee for Environmental Monitoring of Forest Insect Control Operations are given. These pertain to research and monitoring needs; information exchange between governments, industry and the public; budworm control strategies; and coordination of surveillance and control efforts.

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FOREWORD

The EMOFICO Committee is a voluntary association of university researchers, government scientists, and consultants who share a common interest in studying the environmental impact of forest insecticide spray programs in New Brunswick. This volume represents the first published compilation of reports from the Committee since responsibility for EMOFICO was transferred from the University of New Brunswick to the Department of the Environment. The report covers the 1980-81 period.

The Committee's central objective is to scientifically assess the distribution of sprayed chemicals in the environment, and the impacts of these materials on natural systems and wildlife. It is important to emphasize that human health issues and impacts of spray chemicals on the target organism are not issues covered by the Committee's terms of reference.

EMOFICO meetings provide an opportunity for scientists to discuss problems and advances in techniques for monitoring and evaluating the effects of spray insecticides. The research reported in this document represents the disciplinary interests of the individual researchers and their supporting agencies. The Chairman does not direct the research being conducted by members of the Committee.

It should be noted that this EMOFICO report is a compilation of summaries prepared to assist a broader audience in becoming familiar with a wide range of environmental research. These summaries have been approved by the individual authors as accurately representing their work. However, readers who wish to examine more detailed information on the specific research projects are encouraged to make direct contact with the authors in question.

D. I. Besner
Chairman, EMOFICO

Editor's Note: The Committee also wishes to express sincere appreciation to the following individuals for their valuable assistance in reviewing the french language version of this report from a technical perspective:

Mr. Thaddée Renault
Maritimes Forest Research Centre
Canadian Forestry Service
Environment Canada
Fredericton, N.B.

Mr. Guy Brun
Environment Canada
Inland Waters Directorate
Moncton, N.B.

Dr. Victorin Mallet
Faculty of Chemistry
University of Moncton
Moncton, N.B.

Dr. Louis Lapierre
Faculty of Biology
University of Moncton
Moncton, N.B.

SUMMARY OVERVIEW OF ENVIRONMENTAL SURVEILLANCE IN 1980 AND 1981

by

D.R. Townsend
Washburn & Gillis Associates Ltd.

This report deals primarily with environmental surveillance of the spruce budworm control operation in New Brunswick. Although other forest insects in New Brunswick are investigated,¹ large-scale forest pest control operation and environmental surveillance activities pertaining to such operations have been undertaken mainly in the context of spruce budworm suppression. The initial spruce budworm infestation surveys in New Brunswick began during a large outbreak which occurred from 1909 to 1920. Such programs lapsed somewhat after that period, but were resumed on an intensive basis in the early 1940's and have continued since without interruption. Chemical control programs were commenced in 1952. Since 1969, mainly fenitrothion has been used in chemical control programs in New Brunswick directed against the spruce budworm (Prebble 1975).

The area of New Brunswick forest sprayed with insecticide to control the spruce budworm was 1,614,000 ha in 1980, and 1,900,000 ha in 1981. The insecticides used in the operational program in 1980 were fenitrothion and aminocarb (at 210 and 70 g a.i./ha respectively).² In 1981, just fenitrothion was used (at 210 g a.i./ha). Two applications of insecticide were made to most areas (Kettela, 1980a).

In 1980, cool weather in May and June retarded the growth of spruce budworm larvae, but enhanced the growth of fir and spruce shoots thereby increasing the exposure of the larvae and increasing the effect of the sprays. Fenitrothion was used in most areas, but good-to-excellent results were reported for both insecticides. The percentage of foliage saved was considered to be higher than in the previous two

¹For example, the extent of white spruce defoliation by the spruce budmoth (*Zeiraphera canadensis*) has recently been surveyed after severe infestations occurred in the Black Brook Section of Victoria County in New Brunswick (Magasi, 1982).

²Unless stated otherwise, application rates cited in this report indicate the amount (g) of active ingredient (a.i.) applied per unit area (ha) per application.

years, and the degree of protection was similar on balsam fir and spruce. In operational trials in woodlots, spray formulations of Bacillus thuringiensis were not considered to provide satisfactory protection against spruce budworm damage.

In 1981, despite poor weather conditions for spraying, particularly in northwestern New Brunswick, the spray program using fenitrothion was again reported to be effective in reducing budworm damage to the foliage crop. Moderate-to-severe spruce budworm infestations over most of the forest areas of New Brunswick were forecast for 1982 (Kettela, 1981a).

The New Brunswick Department of Natural Resources is in the process of defining a long-term strategy for managing the budworm problem in the context of a new Crown Lands Act. This calls for the continued use of judicious spraying to permit the orderly harvest of older stands as a way of helping to correct a serious imbalance in the age structure of susceptible forests and to minimize the shortages in wood supply that are foreseen from present projections. The strategy also calls for the development of more precise spraying on more sharply-defined forest areas and for the adoption of earlier-intervention tactics to protect younger stands (G. Baskerville, personal communication).

Budworm-susceptible stands constitute a large portion of the forests of New Brunswick and a significant proportion of the forests in the other Atlantic Provinces, and in Ontario, Quebec and the State of Maine. Approximately 37 million ha are moderately to severely defoliated by budworm in eastern Canada. The problem of maintaining timber resources vital to provincial and state economies is complicated by the need to control an organism - the spruce budworm - without harming other organisms in the forest and surrounding environment. Given some uncertainties about the total effects of any control measure on the environment, the resulting constraints on the control program necessary to safeguard the environment, and the size of the control task involved, suppression of the budworm is very costly. Therefore, a premium is placed on any activities which will reduce environmental risks and the expense of the spray operation. As a result, organizations of various types have been formed to facilitate more efficient control of the spruce budworm.

On an international basis, a Canada-United States program dealing with spruce budworms - there are several species in the west - has been formed. CANUSA was organized in 1977 as an international effort to facilitate information exchange, coordinate research and develop control methodologies to provide forest resource managers with alternatives for spruce budworm control and management of forests susceptible to the spruce budworm. Other groups, committees and organizations have been formed to provide a forum for such activities on a smaller or more narrowly-defined scale. A New Brunswick Spray Efficacy Research Group has recently been formed to enhance information exchange and the development and coordination of the various aspects of spray efficacy research. Its goal of using less insecticide closer to the target could result in lessened risk to the environment as spray efficacy is increased. The New Brunswick Committee for Environmental Monitoring of Forest Insect Control Operations (EMOFICO) was formally constituted in 1976 however, for many years previously, other groups were involved in similar functions. EMOFICO functions mainly in the context of the forest insect control operations in New Brunswick but shares membership and information with similar committees formed in other provinces. EMOFICO promotes the coordination of monitoring and research of ecological effects of forest spraying operations, pesticide accountancy, and the exchange of information among members, the public, and government and private organizations. In this, the fourth EMOFICO report¹, environmental surveillance activities

¹Previous EMOFICO reports are as follows:

- (i) Varty, I.W. (ed.) 1976. Environmental effects of the spruce budworm spray program in New Brunswick, Can. For. Serv., Maritimes Forest Centre, Inf. Rep. M-X-67.
- (ii) Varty, I.W. (ed.) 1978. Environmental surveillance of insecticide spray operations in New Brunswick's budworm-infested forests 1977. Can. For. Serv., Maritimes Forest Research Centre, Info. Rep. M-X-87.
- (iii) Varty, I.W. (ed.) 1980. Environmental surveillance in New Brunswick, 1978-79. Effects of spray operations for forest protection against spruce budworm. University of New Brunswick, Fredericton, New Brunswick.

Information concerning the availability of these reports may be obtained from the Secretary of EMOFICO (see address on p. 126).

conducted during 1980 and 1981 are described and recommendations relative to future research and monitoring needs are made.

Wildlife. Decisions on forest spray operations in the context of the wildlife resource must take into account the impact on wildlife habitat.

Forest spray operations may affect wildlife indirectly, through amelioration or degradation of habitat (including food resources) and directly, if the spray itself is detrimental to the health of wildlife. Before decisions are made concerning the spray operation, both the advantages and disadvantages of the operation must be assessed. This is often difficult because wildlife populations show considerable variation in their response to the environment on a year-to-year, season-to-season, and even a day-to-day basis. Data and trend analysis of long-term survey data may facilitate a greater understanding of the implications of results gained from research work of short duration.

In New Brunswick, attention has been focused on the white-throated sparrow and the red squirrel as potential indicators of the effects of the spray operation on wildlife. In studies of ingestion toxicity in white-throated sparrows in New Brunswick in 1980 and 1981, it was found that: (1) single experimental doses of as little as 7 mg fenitrothion/kg reduce growth rates in white-throated sparrow nestlings, (2) the food resource of nestlings contains up to 17 mg fenitrothion/kg after operational spraying, and (3) nestlings eat approximately their own weight in food daily.¹ Therefore, if nestlings eat their own weight in contaminated food, the daily exposure would be sufficient to produce the growth reductions that were observed in an experimental dosing study. It was concluded that slower nestling growth rates observed after operational fenitrothion spraying were a direct result of exposure to the pesticide. Although the implications of the slow growth rates and lower fledging weights are unknown, studies elsewhere indicate that fledging survival is reduced, especially at times of poor food supply or inclement weather conditions.

¹See summaries in this report by Busby (p. 63), Pearce and Busby (p. 63), Busby (p. 64); and Pearce (p. 65).

Measurement of brain cholinesterase (ChE) levels was used to indicate the degree to which birds have been affected by organophosphate and carbamate insecticides, with slightly reduced levels indicative of exposure, and pronounced reduction of cholinesterase activity being indicative of insecticide toxicity. Two applications of Matacil^R 180 Flowable at 70 g a.i./ha over small plots had no significant effect on brain ChE of forest-dwelling songbirds.¹ Some potentially lethal levels of ChE reduction were detected in a small proportion of samples of white-throated sparrows and warblers collected from an area sprayed with fenitrothion at 280 g a.i./ha.² With fenitrothion, the margin of safety for the most vulnerable songbirds is sufficiently narrow that inadvertent overdosing (e.g., over-swathing of an area) can result in undesirable impact. It was concluded that in the context of the New Brunswick operational spray program, aminocarb presents less immediate hazard to exposed songbirds than does fenitrothion (at application rates currently prescribed in this program).

A long-term study of the red squirrel (Tamiasciurus hudsonicus) has indicated that, in unsprayed areas of southeastern New Brunswick forests, home ranges tend to be 40-60% higher, and population levels tend to be lower than in sprayed areas (L.E. Lapierre, personal communication). White birch (Betula papyrifera) and red maple (Acer rubrum) browse eaten by white-tailed deer (Odocoileus virginianus) has been analysed for fenitrothion. It was concluded that, in the winter when deer are yarding and these browse items are an important part of their diet, the concentrations of fenitrothion are sufficiently low that digestion of this browse should not be adversely affected (Lapierre, 1982).

Pollination. Many plants species are to some degree dependent on pollination by insects, particularly domestic and wild bees. The potential for impacts of forest spraying on insects and the pollination process is now generally recognized and, in more recent years, particular impacts have been studied. In 1980, in an area of New Brunswick sprayed with aminocarb, the fruitset of

^{1, 2} See summaries in this report by Busby et al. (p. 60 and 61).

two species of plants was investigated. A lower fruitset occurred in a plant species (Cornus canadensis) pollinated by insects affected by aminocarb than occurred in another species (Maianthemum canadense) pollinated by insects not affected by aminocarb. A more definitive statement of effects on pollination of these plants would be possible if this study were repeated with larger sample sizes (C. R. Plowright, personal communication).

Some adjustments in the operation of the spray program have been made to lessen effects on pollinators. Increases in buffer zone width adjacent to blueberry fields and orchards have provided greater safety to pollinators in these areas. In an insecticide drift monitoring program at four commercial blueberry fields in 1980, the levels of drift detected were small and bee activity and blueberry fruitsets did not indicate harmful effects from the spray operation.¹ Further such monitoring was not carried out in 1981 because untoward effects of insecticide drift on such areas were considered unlikely. Such measures as buffer zone changes are not feasible for protection of wild pollinators in the forest. Pollinating insects might be better protected by more selective use of insecticides. For example, aminocarb at operational application rates appears to generally have less impact on bees than does fenitrothion.

Forest Arthropods. In a four-year study (1977-1980) of predaceous arthropods in fir stands, one study plot was treated annually with fenitrothion, a second study plot was treated annually with aminocarb and a third plot was used as a control.² All three study areas had similar spider communities (with a few species dominating), and similar perennial population density trends. Species diversity and dominance differed between the study areas, and fewer spider species were found on the fenitrothion study plot than on the other plots. The perennial dynamics of the predaceous insect complex were parallel in all plots; however the mean populations densities of predaceous insects were lowest in the fenitrothion plot, intermediate in the aminocarb plot and highest in the untreated plot.

^{1,2}See summaries in this report by (1) Wood (p. 69) and (2) Varty (p. 70).

In 1981, effects of different Matacil^R formulations on the native arthropod fauna of balsam fir were investigated.¹ Pending deposit assessment results, it appears that differential knockdown of the arthropods was achieved with the different formulations.

Freshwater Fauna. Effects of fenitrothion forest sprays on aquatic invertebrates and fish have been examined in many studies. No marked negative effects on fish in natural waters have been found. Although increased drift of invertebrates often occurs, the impact of the most frequently tested formulation (fenitrothion dissolved in Dowanol, emulsified with Atlox, and diluted with water) is considered sufficiently small to be tolerable at the standard application rates used in New Brunswick.

In a study of the partitioning of fenitrothion and invertebrate drift in water, two formulations of fenitrothion were tested as ground sprays: one an oil solution and one an emulsion, with the adjuvants used operationally in New Brunswick in 1981.² Complete mixing of both formulations in the water column occurred within an hour after the spray application, and concentrations of fenitrothion in water samples taken in back eddies were of the same order as those which occurred in mid-stream samples. A significant portion of the fenitrothion was sorbed on suspended particulates in the streams and attached to the organic fraction of stream bottom sediments. The vertical distribution of the invertebrate drift was affected more by the hydrodynamics of the stream flow than by the insecticide formulation.

Another study dealt with the movement of aminocarb from ground sprays through the surface microlayer of ponds and effects on the resident microbiota.³ The transfer of aminocarb from upper to lower strata of the ponds and the eventual diminution of the aminocarb concentration were found to depend on physical mechanisms such as wind. No discernible impacts on

¹⁻³ See summaries in this report by (1) Millikin (p. 73), (2) Eidt and Mallet (p. 76), and (3) Elner and Wildish (p. 77).

microbial activity were seen. Following the spray applications (at greater than the operational application rate) to each of the three treatment ponds, carbon assimilation by pond algal communities was stopped completely. The carbon assimilation resumed within 72 h.

Toxicology. The toxicity of components of aminocarb and fenitrothion spray formulations has received considerable attention in laboratory toxicity tests. Cyclosol 63^R is a registered insecticide solvent oil found in some fenitrothion formulations. Because of the synergistic effects of fenitrothion and Cyclosol 63, the safety margin for aquatic species in programs utilizing such formulations may not be as great as previously predicted.¹ In bioassays, nonylphenol, an alkylphenol occurring in some aminocarb formulations, had lethal effects on rainbow trout and Daphnia at concentrations which were greater than those normally observed after forest sprays, but within the range of local concentrations that can occur after sprays at a higher application rate equal to the maximum allowable under terms of the Agriculture Canada registration. Further testing on shrimp, lobsters and juvenile salmon indicated that the toxicity and bioconcentration of alkylphenols were sufficiently high to warrant more detailed study of their sources, environmental fate, and effects.² A study involving an evaluation of the toxicity of the constituents of Matacil^R (approximately 20% aminocarb, 50% nonylphenol, and 30% diluent oil) to cultured cell populations indicated that the toxicity of the formulation was due principally to the nonylphenol constituent.³

A Matacil 1.8F^R concentrate without a nonylphenol component was found to be about one tenth as toxic to rainbow trout as Matacil 1.8 concentrate which contained the same quantity of aminocarb but also nonylphenol.⁴ Rainbow trout bioassays of components of the proposed operational water

¹⁻⁴See summaries in this report by (1) Ernst et al. (p. 81); (2) McLeese et al. (p. 83); (3) Li et al. (p. 84); (4) Doe et al. (p. 82)

formulation of Matacil 1.8F indicated that the toxicity of the formulation was due almost entirely to the aminocarb component.¹ For the proposed operational oil formulation, only 63% of the acute toxicity could be attributed to the aminocarb component, 37% to the diluent oil component. The aquatic invertebrates, Daphnia pulex, Anodonta sp. (a freshwater bivalve), and Mytilus edulis (a saltwater mussel) were tested for acute toxicity of water and oil formulations of Matacil 1.8F. D. pulex was the most sensitive to both formulations. Although Matacil 1.8F contains finely-milled particulate aminocarb which has the potential to be bioaccumulated, tests using M. edulis, a filter-feeder, indicated a bioaccumulation potential for Matacil 1.8F similar to that for Matacil 1.8D which does not contain finely-milled aminocarb. In an investigation of subacute toxicity of fenitrothion (technical grade) on male rats, at dosages between 2.5 and 20 mg/kg [body weight]/day for 30 days, few deleterious effects were observed other than those inhibitory effects which commonly follow the administration of any cholinesterase inhibitor².

A hazard assessment model developed for use in the assessment of the relative effects of chemicals currently in use, or under consideration for use, in broad-scale forest spraying is described.³

Insecticide Analysis. Following a 1977 EMOFICO recommendation for better analytical techniques for the measurement of aminocarb and its degradation products, this type of analysis was improved in 1978 and 1979. There have been subsequent advances in a multi-residue analytical method for aminocarb and some of its degradation products⁴. The stability of aminocarb in water was investigated and some of its breakdown products were identified.

Insecticide Distribution and Persistence. The downwind drift of insecticide spray clouds, although necessary to spread the insecticide homogeneously over budworm-infested forest, inevitably carries a portion of the spray formulation

¹⁻⁴ See summaries in this report by (1) Doe et al. (p. 82); (2) Trottier et al. (p. 84); (3) Zitko and McLeese (p. 85); (4) Levesque and Mallet (p. 92).

into non-target areas.¹ The New Brunswick Task Force on Drift was set up in 1978 by the New Brunswick Department of Natural Resources in consultation with the Department of Health to review information on drift. Within the Task Force, an interdisciplinary group is modelling and testing off-swath movement and deposition of aerosols and vapors in the interests of improving operational efficacy and hazard evaluation of spray programs. Because of the multiplicity of factors affecting drift, mathematical modelling is being used extensively for prediction of drift behavior. To illustrate the complexities involved in assessing drift behavior, such variables as spray plane height, forest terrain, droplet mass, vegetative cover, weather, and spray formulation affect the percentage deposition of spray droplets. In terms of weather, rainfall has been shown to wash a high proportion of fenitrothion from spray plumes, and can be more important than dry fallout in contributing to the deposition of drift in non-target areas.²

A series of models has been developed to provide a better understanding of spray operations in terms of:

1. droplet spectrum generation by wind shear at the spray nozzle;
2. transport of the aerosol by gravity and wind, and the trailing vortices (or wake) of the aircraft;
3. deposition as influenced by formulation, droplet size, turbulence, and receptor characteristics; subsequent vapor flux deposits; and
4. biological effect.

A near-field drift model is described which can be used to predict air concentrations of droplets at any height, and deposition on tree foliage and the ground, at distances up to 500m downwind as a function of time.

Both this and a far-field drift model (covering transport beyond 1km downwind) have produced useful information on drift behavior. These models however require further refinement and field validation, especially in relation to vortex behavior and vertical dispersion of the aerosol cloud.

Various models have been developed with which exposure to drift at various downwind distances can be predicted. Such information is useful

¹⁻² See summaries in this report by (1) Varty (p.94), and (2) Bailey and Belliveau (p. 100).

when buffer zone widths are to be established or adjusted around inhabited areas and water bodies. Indications of the amount and spatial extent of drift may also be inferred from systematic air monitoring programs, ecological effects occurring outside the spray zone which can be correlated with spray operations, and from the analysis of residues in ecosystems outside the spray zone.

The chemical stability of insecticides in drift is of concern because the toxicological significance of the insecticide degradation products formed in the vapor plume is unknown. The duration of spray cloud passage over an area is also important. Fenitrothion spray clouds have been found to pass over sampling sites within and near spray blocks with a maximum duration of 5 - 15 min for the first spray cloud (there are also secondary clouds).¹

One practical goal of drift research is to learn how to use less insecticide with greater efficiency and less drift, by utilizing knowledge of emission spectra, favourable weather, and droplet impaction efficiency.

In 1980 and 1981, researchers helped to fill some of the gaps in information dealing with the distribution and persistence of insecticides and their residues. After the application of three different aminocarb formulations to three different plots in a New Brunswick forest ecosystem, residues in balsam fir foliage were usually found to be small but they differ according to the formulation.² Usually residues from oil formulations were larger than those from water formulations. Residues levels were extremely small in soil compared to forest litter and persisted longer at detectable levels in the litter. Residues of aminocarb disappeared very rapidly from streamwater.² Sediment samples contained low levels of aminocarb which persisted for a short time (maximum 20.2 ppb five min after the water formulation had been sprayed). When the water formulation was used, aminocarb usually accumulated in fish at low concentrations, but no mortality or behavioral changes were observed.

Surveys of fenitrothion residues in New Brunswick in 1980 and 1981 indicated that quantities of fenitrothion were low and did not persist in

¹⁻²See summaries in this report by (1) Wood (p. 102), and (2) Sundaram (p. 103).

streamwater, air, soil litter and foliage.¹ Aminofenitrothion was the only degradation product detected in these samples. Fenitrothion was detected in a beaver pond (for 18 consecutive days) and aminofenitrothion was also detected there. Fenitrothion was detected only occasionally at low levels in air samples.

In another investigation, low levels of a fenitrothion derivative, possibly the nitroresol 3-methyl-4-nitrophenol, were found in many of the samples of woodcock collected from spray zones.² In a study of fenitrothion accumulation by plants and invertebrates in two New Brunswick streams, before experimental spraying took place, fenitrothion residues were present in certain of the aquatic plants and animals.³ These residues may have occurred as a result of drift from a spray operation in the vicinity during the same spray season; however because some insecticide residues do persist over extended periods (e.g., DDT), the incidence of repeat spraying of an area or over-swathing, is important. Barring substantial changes in infestation levels or spray strategy, the chances of a particular area being sprayed in 1981 and resprayed in 1982 are between 10 and 20%, and again in 1983, between 5 and 10%.⁴ Following experimental spraying in the fenitrothion accumulation study, all plants and animals sampled contained fenitrothion residues. High concentrations of fenitrothion persisted in the liverwort (*Solenostoma* sp.) during seven days of observation after spraying. Fenitrothion residues in other organisms decreased markedly by seven days. The only degradation product found was 3-methyl-4-nitrophenol which was found in two early post-spray plant samples and one invertebrate sample. The concentrations of fenitrothion and 3-methyl-4-nitrophenol found in the plant and animal samples were not considered likely to have acute lethal effects on fish, birds or mammals which ingest them.

Studies of Candidate Insecticides. Assessment of the efficacy and environmental impact of insecticides under consideration for potential use in forest pest control programs is an ongoing process as new insecticides and new formulations are continually being developed. Given below are descriptions of studies conducted in New Brunswick on candidate insecticides in 1980 and 1981.

Sevin-2-Oil^R (carbaryl) and Reldan^R (chlorpyrifos-methyl).

Studies of the efficacy and environmental impact of experimental applications

¹⁻⁴See summaries in this report by (1) Mallet (p. 104 and 105), (2) Pearce (p. 106), (3) Sosiak (p. 107), and (4) Eidt (p. 109).

of carbaryl and chlorpyrifos-methyl at rates proposed for spruce budworm control were conducted in 1980.

Carbaryl. The greatest concentrations of carbaryl residues in streamwater were detected immediately after the spray applications, but the residue levels declined rapidly thereafter.¹ Some disruptions in normal aquatic invertebrate drift occurred after the spray applications, but the overall effect on benthic populations was considered negligible. Food supplies for brook trout and slimy sculpin did not appear to be reduced and there was no evidence of mortality of brook trout in the spray area.

Chlorpyrifos-methyl. Residue levels of chlorpyrifos-methyl in streamwater peaked briefly after the spray applications and then rapidly declined. The residue detected in stream sediments, and in wild brook trout and slimy sculpins, declined to small concentrations within 10 days.² By contrast, the residues in balsam fir foliage (particularly current foliage), forest litter and soil persisted for long periods of time (at very small concentrations). The knockdown of non-target terrestrial arthropods with this spray was slight, and forest songbird populations remained stable throughout the study period with little evidence of territorial disruption.

Although marked changes in the level of aquatic invertebrate drift occurred, no significant depletions in stream benthos were found. No mortality of native brook trout and Atlantic salmon parr occurred in the spray area. No significant changes in the diet and condition factors of brook trout and slimy sculpins were found.

Permethrin. Experimental permethrin applications were studied in 1980 to assess environmental impact on selected aquatic and terrestrial organisms. One 600 ha block received a single application and another 600 ha block, two applications four days apart.³

The levels of permethrin residues in streamwater samples peaked after the second of two applications in the double application block, and small concentrations of residue persisted at most sample sites for at least 48 h.⁴ Larger concentrations of permethrin residues were found in fish in

¹⁻⁴ See summaries in this report by (1) Kingsbury *et al.* (p. 110), (2) Sundaram (p. 111), (3) Kingsbury and Kreutzweiser (p. 112), and (4) Kreutzweiser and Wood (p. 113).

the double application block, and these persisted for a longer period of time. Different amounts of residue accumulated in the different species of stream fish, e.g., residues were found in Atlantic salmon and brook trout, but not slimy sculpins or American eels. Although laboratory toxicity tests indicate that exposure to permethrin (and related pyrethroids, cypermethrin and fenvalerate) can be lethal to Atlantic salmon at low concentrations,¹ the levels of permethrin found in the test streams did not appear to have lethal effects on Atlantic salmon parr that were in either their first year of life (0⁺ parr) or their second (1⁺ parr).² It appears that double (but not single) applications of permethrin at 17.5 g a.i./ha can temporarily reduce juvenile Atlantic salmon population density and growth rate, possibly because benthic invertebrates on which they feed were markedly reduced in the double application block. Both Atlantic salmon (2⁺ parr), and particularly brook trout, fed opportunistically on the increased invertebrate drift, and salmon shifted their diet. Feeding activity of slimy sculpins did not appear to be adversely affected by the spray applications.³

After the spray applications, large numbers of dead and stressed invertebrates were found in the drift, species diversity was reduced in the double application site, and recovery of stream benthos populations was slow.^{3,4} Effects of permethrin on stream benthos were considered to be more severe than those of any of the currently used spruce budworm insecticides.

Low concentrations of permethrin are lethal to shrimp and lobsters as are cypermethrin and fenvalerate.¹ Crayfish collected in streams in the permethrin spray blocks showed some behavior changes after the spray applications and some mortalities occurred in the double application block.² Crayfish analysed for permethrin were found to contain no traces of residues. Further investigation is necessary to clarify the implication of effects on crayfish behavior and survival.

The amount of residual permethrin accumulated in stream sediments was small; more was detected in forest litter.⁵ On pin cherry blossoms and balsam fir foliage, the variety of arboreal and flying arthropods affected by permethrin and the duration of the spray effects were similar. Pesticide-induced knockdown of arthropods was immediate, but did not persist beyond 48 h.⁶

¹⁻⁵ See summaries in this report by (1) McLeese *et al.* (p.119), (2) Sosiak (p. 115), (3) Kreutzweiser (p. 118), (4) Eidt (p. 114), (5) Kreutzweiser and Wood (p. 113), and (6) Kreutzweiser (p. 118).

Regulatory Aspects of Environmental Surveillance. The Pest Control Products Act governing the use of pesticides in Canada is administered by the Pesticides Division of the Plant Products and Quarantine Directorate, Food Production and Inspection Branch, Agriculture Canada. The pesticide registration process, and functions and regulations of the federal Pesticide Division sections and Province of New Brunswick regulatory agencies are described as are response procedures to be used by spray applicators and monitoring agencies, in the event of aerial and ground mishaps which result in the accidental placement of pesticides in the environment.

Experience in Quebec. Declines in the levels of budworm infestation which started in 1976 did not continue into 1980. Damage increased by 1.9 million ha to a total budworm-damaged area of 15.5 million ha of which moderate and severe damage occurred in 4.3 million ha. Approximately 138,500 ha of budworm-infested forests received spray applications, 166,300 ha with chemicals, 22,200 with B.t. Two chemical applications were made per site, but only one application of B.t. was made per site. Relative to the chemical treatments, mainly fenitrothion was used (at 210 g a.i./ha). For the second spray application only, at some sites (55,200 ha) Matacil^R was used (at 52 g a.i./ha). Experimental spray applications of a synthetic pyrethroid, Ambush^R, at 17.5 g a.i./ha were reported to give satisfactory results when two applications were used. Experimental spraying of Dipel 88^R (a new B.t. formulation in oil) was found to be effective (Auger et al., 1980).

In 1980, a sampling network was maintained to assess the presence and distribution of residues in air, water and foliage. In cooperation with the Forest Pest Management Institute, research was conducted into the impacts of experimental permethrin sprays on aquatic invertebrates, terrestrial arthropods, and small mammals. No measurable impact on the small mammals and ground-dwelling invertebrates was detected, however the number of terrestrial arthropods on stream bank foliage and the forest canopy was reduced for 48 h post-spray. The stream benthos was initially dramatically reduced, but after 2 1/2 months repopulation of the sprayed areas was evident (report in preparation). In an investigation comparing the effects of oil-based formulations of fenitrothion and aminocarb on stream benthos, the fenitrothion

formulation was found to be the more toxic. The impact of the pesticides was suggested to be related less to the different sensitivities of different organisms, but more to their ability to escape contact with the contaminants (Ahern et Leclerc, 1981).

In 1981, of the 704,100 ha treated with chemical pesticides, about 80% of the area was sprayed with Matacil^R, less than 5% (31,000 ha) was sprayed with B.t. and the remainder with fenitrothion. There were two and sometimes three applications of the chemical pesticides (at the application rates given above). A single application of B.t. Dipel 88 (at 19.76 B.I.U./ha) produced similar results to those of the chemical treatments. Experimental applications of another B.t. formulation, Thuricide 32B^R, were reported to produce satisfactory results, but results with Futura 64B were not conclusive. The overall success of the operational spray program in 1981 was considered good (Anonymous, 1981a.)

On the basis of monitoring and research experience in the province of Quebec, and an extensive review of information from outside sources, Gaboury et al. (1981) concluded that the fenitrothion and aminocarb formulations and biological insecticides (B.t.) used in the spray programs in Quebec have caused little environmental damage. Of the three operational insecticides used, B.t. was considered to be the least likely to cause environmental damage although both fenitrothion and aminocarb showed little persistence in the physical environment or the biota. Generally, aminocarb appears to have had little effect on the ecosystems examined to date. Fenitrothion appears generally to have had little effect on non-target species, however, some effects on terrestrial and aquatic insects have been observed. Such effects, except on pollinators, have usually been temporary, and affected populations seem to recover quickly. The authors caution, however, that long-term effects remain difficult to evaluate. They also noted gaps in knowledge about effects of the solvent Cyclosol 63^R used in fenitrothion formulations.

Experience in Nova Scotia. A dramatic increase in the extent and severity of budworm defoliation occurred in 1980. About 1.4 million ha of defoliation occurred as compared to 1.1 million ha in 1979. Detectable levels of defoliation decreased in 1981 to 700,000 ha. The decrease in Cape Breton

Island was possibly due to the extensive areas of dead and dying forest already present. However, in the mainland areas, the reasons for the population decline are not clear (Kettela, 1980b, 1981b).

Subsequent to a 1979 investigation of the efficacy and environmental impacts of the use of B.t. (Nova Scotia Department of Lands and Forests, 1980), selected high-value spruce and fir stands in Nova Scotia were sprayed with B.t. formulations in both 1980 and 1981. Thuricide 16B^R was used at 20 B.I.U./ha in 1980 and 1981, and Dipel 88 was used at 22 B.I.U. in 1981. The spray programs were considered to have provided generally acceptable protection in both years, with some minor exceptions in 1980 (Smith, 1980, 1981). B.t. has been tested for overwintering resistance and it appears to survive winter conditions.

Effects of B.t. on antibody production in guinea pigs and antiserum levels in humans have been assessed. No effects on antibody production were found. On the basis of the assessment of antiserum level effects, it was concluded that B.t. applications did not constitute a major health hazard at operational dosages (T.D. Smith, personal communication).

Experience in Maine. The current budworm outbreak affects nearly all the approximately 3.2 million ha of spruce-fir forest in Maine. Although the development of budworm larvae in 1980 was retarded by cool weather, only small numbers of unhealthy larvae were found. The rate of survival of budworm larvae in untreated areas was similar to that of other years. Carbaryl (Sevin-4-Oil^R) was used in spray blocks remote from permanent human habitation and B.t. was used in blocks near populated areas within the settlement corridors. Carbaryl was applied both in single application treatments at 2102 g (1681 g Sevin and 421 g #1 Fuel Oil)/ha and double applications spaced 5 to 7 days apart at 1401 g (1120 g Sevin and 281 g #1 Fuel Oil)/ha. Two commercial formulations of B.t. were used, Dipel 4L^R and Thuricide 16B^R (both at 19.77 B.I.U./ha). About 80,000 ha were treated with B.t.; 410,000 ha were treated with carbaryl. The 1980 suppression program was reported to be highly successful on most areas treated (Dyer et al., 1980).

On the basis of a demonstration project, the Maine Bureau of Forestry and the U.S. Forest Service concluded that it was logistically feasible to conduct a large-scale B.t. application with helicopters. The efficacy of budworm population control was considered to be lower than would be expected with chemical insecticides, but was thought to provide sufficient foliage protection to prevent tree mortality for the current year (Dyer et al., 1980).

Based on environmental research conducted in the context of the 1980 Maine spray program, the Maine buffer zone policy was effective in keeping the level of carbaryl entering streams low, and the low levels of carbaryl detected were found to have little impact on brook trout fry or their food supply. Refugia (non-sprayed areas) were not found to be very effective in providing a base for re-establishing populations of stoneflies affected by carbaryl but more investigation of refugia was considered to be necessary to evaluate refugia as a factor mitigating aquatic insect depletion. Post-spray repopulation of streams by stoneflies was slow, and only partially complete by the time the area was sprayed again. Populations of stoneflies which function in the breakdown of leaf litter in streams were not found to be affected in the early post-spray period (14 days); however, over the long-term (142 days later) slower leaf processing occurred in sprayed streams. An assessment of the impact of carbaryl on macroinvertebrate fauna of woodland ponds indicated that significant reductions of some macroinvertebrate populations occurred (Anonymous, 1981b).

Other research indicated that carbaryl affected the feeding behavior of young black ducks in the spray area. Following carbaryl applications, insectivorous birds (warblers) were temporally displaced from some forage areas and foraged at different heights in the trees.

In 1981, about 411,000 ha of Maine forest was sprayed with carbaryl and 51,200 ha was treated with B.t. (Dipel^R and Thuricide^R formulations) and about 12,500 ha were treated with acephate (Orthene^R). Many application variations were tested in 1981 including split applications of carbaryl timed to protect spruce, fir and hemlock, increased dosages of B.t. (Dipel and 24B Thuricide^R) a high-dosage split application of Dipel, and acephate applied from large jet helicopters rather than fixed-wing aircraft. Conditions were favourable for a successful spray operations, and very good

levels of foliage protection were reported. With carbaryl, double applications were more effective than single applications. Protection in 1981 with acephate was equivalent to that with carbaryl. B.t. applied at a rate of 19.77 B.I.U./ha was not generally effective. Dipel and Thuricide (at 29.63 B.I.U.) gave results similar to those produced by carbaryl and acephate. At 29.65 B.I.U. of B.t./ha, reduction of the budworm populations was very rapid. Unlike previous experience with B.t. in Maine, applications were considered successful in areas of high-to-very high budworm populations; and rain seemed to have much less effect on spray efficacy at a 29.65 B.I.U./ha as compared to smaller application rates. Double applications of 19.77 B.I.U./ha (totalling 39.5 B.I.U./ha) were less consistently effective (Trial, 1981).

In conjunction with the 1981 budworm spray program, research on the following topics was conducted: (1) the short and long-term effects of carbaryl on pond microinvertebrates and its persistence in water sediment; (2) the effectiveness of aquatic invertebrate refugia; (3) effects of B.t. on Trichoptera; (4) effects of Sevin-4-Oil^R on fruit set and its potential consequences for wildlife in a spruce-fir forest; (5) effects of acephate on bird reproduction through direct effects on nestlings or indirect effects related to lack of food. In addition to these projects, literature on the behavior of carbaryl in the environment was reviewed, and the concentrations of carbaryl at river mouths were monitored.

The area designated as facing a high or extreme hazard due to budworm infestation was reduced from 2,025,000 ha in 1980 to 1,822,500 ha in 1981. In 1982 Sevin-4-Oil, Orthene and B.t. (at 29.65 B.I.U./ha) will be recommended for use in the suppression program, and a long-term environmental monitoring plan will be established (Trial, 1981).

For forest protection programs after 1981, the Maine Department of Conservation has recommended: (1) the reduction of reliance on chemical spraying as the basic management tool for budworm control; (2) movement of responsibility for the spray operations themselves to the private sector; (3) an end to all public subsidies for spray operations; and (4) the maintenance of a vigorous effort - both state and federal - in survey and detection, research, technical assistance, and monitoring and regulation of

private spray operations (Barringer, 1980). Of the alternatives suggested in the Department's proposed 5-year (1981-1985) Spruce Budworm Integrated Pest Management Program, the alternative preferred by the U.S. Forest Service involves an increase in silviculture, and changes in the patterns of tree utilization and product marketing concurrent with a reduction in the use of chemical insecticides and an increased use of biological insecticides (U.S. Department of Agriculture, Forest Service, 1980).

Experience in Newfoundland. Unseasonable weather in 1980 slowed larval development, and defoliation was not evident until late July (Anonymous, 1980). The total area of moderate to severe defoliation decreased to 926,000 ha from 972,600 ha in 1979. No active budworm infestations occurred in Labrador in 1980 (however, two pockets of infestation did occur in 1981).

In 1980, an operational and an experimental spray program was conducted using various B.t. products, formulations, and application rates. Monitoring of effects of B.t. on the environment was limited in 1980 to a study of the short-term impact on terrestrial arthropods. No impact was observed. Also in 1980, the persistence of Matacil^R residues from the 1978 spray operations in soil and vegetation in spray area was investigated. Trace residues were detected in both. Long-term effects of the 1978 spray operation on soil-dwelling arthropods were difficult to assess because conflicting results were obtained. Further investigation was recommended. On the basis of a 1980 investigation, some changes in the numbers of birds present in areas sprayed with aminocarb in 1978 (at 70 g a.i./ha) appear to have been related, either directly or indirectly, to spray effects of the 1978 program probably through food supply disruptions. (A Newfoundland and Labrador Department of Environment report on environmental monitoring is in preparation.)

In 1981, the predicted area of moderate and severe defoliation due to budworm was 800,000 ha; however, it occurred only on about 300,000 ha (Anonymous, 1981c). No one natural control factor could be singled out as a dominant reason for the collapse of the budworm population. It was not possible to attribute a large proportion of larval mortality to the usual biotic control factors such as predators, parasites and known diseases, but

the wet and cold weather occurring in the summers of 1980 and 1981 and the associated lack of feeding by larval may have contributed to the mortality of the larvae. The Department of Natural Resources conducted a budworm control program using B.t. and aminocarb on a total of 250,000 ha. Based on egg-mass surveys, the area of moderate and severe defoliation is forecast to decrease markedly in 1982 to 70,000 ha. No defoliation is forecast for 1982 in Labrador.

In 1981, the long-term monitoring of bird responses to the aminocarb spray program was continued as was an extensive survey of water samples from lakes and rivers for spray residues. Populations of soil and arboreal arthropods were also monitored. The results are pending.

Fisheries and Oceans Canada is conducting a study to determine the long-term effects of aerially-applied pesticides on aquatic life in the Experimental Ponds Area, central Newfoundland. The Area includes three ponds and four tributary streams at the headwaters of the Northwest Gander River. The research approach involves documenting ecosystem dynamics, application of experimental spray, and pre- versus post-treatment comparisons coupled with treated versus untreated comparisons. At the present time, pre-spray ecosystem dynamics are being documented. Data on water chemistry and physics, primary production, and zooplankton, phytoplankton, zoobenthos, and fish populations have been collected. The data will be analysed with the aim of developing the capacity to predict long-term composition and seasonal abundance of biota in shallow, brown-water ponds of Newfoundland.

Environmental impacts associated with particular forestry practices in eastern Canada including the impacts associated with spruce budworm control programs have recently been reviewed in the context of the Newfoundland and Labrador Royal Commission on Forest Protection and Management (Anonymous, 1981d; Ernst et al., 1981).

Experience in Ontario. In the operational spray programs conducted against spruce budworm in 1980, about 10,470 ha of high-value forests and plantations were treated with aminocarb and B.t. (Thuricide 16B^R and Novabec 32B^R) at

various application rates. The 1980 spray protection results were considered the best attained in 12 years of spraying (Carrow et al., 1980). Some spray blocks received one application, others two. All materials and treatments were reported to provide satisfactory protection, but the best result on balsam fir was obtained by a double application of B.t., or aminocarb followed by B.t.

The efficacies of three other insecticides, acephate (Orthene 97 SP^R), dimethoate (Cygon 4E^R) and permethrin were tested (at application rates of 560-1120 g a.i./ha, 560 g a.i./ha and 17.5 g a.i./ha respectively). Dimethoate appeared to be totally ineffective for either foliage protection or population control, better results were reported for acephate. Results of permethrin applications were considered to be generally unsatisfactory. In other tests, single applications of a high volume of aminocarb formulation (86 g a.i./4.7 L of formulation/ha) were reported to produce equally good or better results than did double applications of a lower volume formulation (86 g a.i./1.4 L/ha). From a test comparison of a new B.t. product, Dipel 88^R, with one of the products used in the operational program (Thuricide 16B^R), neither product was considered to have provided good foliage protection. Good foliage protection was however reported for experimental sprays using the spruce budworm NPV virus.

The impact of aminocarb on non-target aquatic fauna was monitored, as was long-distance drift of this insecticide. Observations of the drift indicated that the fine droplet spectrum of the spray may remain suspended in the air mass for 10 days and generally disappears through photo-oxidation. The concentration of aminocarb detected in this air monitoring program were considered to pose no hazard to human health.

The area of forest infested by spruce budworm declined to about 18.2 million ha in 1981 from 18.85 million ha in 1980 with the decline predicted to continue into 1982. The area of budworm-associated tree mortality, however, increased from about 8.4 million ha in 1980 to 11.2 million ha in 1981 (Appeljohn and Howse, 1981). In the 1981 effort to protect high-value forests and plantations, the Ministry of Natural Resources treated about 10,200 ha with a variety of insecticides including aminocarb (3,200 ha at 86 g a.i./ha), Dipel 88^R, (3,100 ha at 24 B.I.U./ha), Thuricide

16B^R and 32B^R (3,500 ha at 13-20 B.I.U./ha) and spruce budworm NPV virus (100 ha). The only environmental monitoring undertaken in 1981 was a sampling program to determine residues of aminocarb remaining one year after application. Results are pending.

Conclusions. In spruce budworm control operations in New Brunswick, the distribution and fate of the insecticides used, and especially their breakdown products will always be difficult to assess. Detrimental effects on some organisms (songbirds, aquatic invertebrates, and pollinators) are known. It is impossible to say if such effects are indicative of more lasting or widespread effects or if they are transitory effects on particularly vulnerable organisms receiving spray deposits. It is also not clear as to how the observed effects translate in terms of the long-term effects on populations of the species involved. In the context of the New Brunswick spray program, the use of aminocarb as compared to fenitrothion formulations appears to provide a greater margin of safety with respect to songbirds, aquatic organisms and pollinators. In assessments of the impact of insecticide regimes, the toxicity of all individual components and the formulated product should be considered, not the toxicity of just the active ingredient. Further investigation of drift should make it possible to increase spray efficacy and reduce risk to non-target organisms.

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RECOMMENDATIONS

A Consensus Opinion of EMOFICO Committee

1. It is recommended that the New Brunswick Department of the Environment set aside an annual environmental surveillance fund to support research and monitoring of forest insect control operations.
2. It is recommended that the New Brunswick Department of the Environment review, on a continuing basis, the rationale for the specifications of buffer zones.
3. It is recommended that monitoring, research and regulatory agencies make a greater effort to explain the significance of their findings to the public.
4. It is recommended that regulatory agencies recognize the possible need for aerial spray programs involving multiple applications of one or more pesticides against two or more forest pests, in one area, in one year, and establish criteria and guidelines for such eventualities.
5. It is recommended that, if chemical spraying of forests for foliage protection from spruce budworm continues, regulatory agencies take into account the fact that EMOFICO researchers find fewer environmental effects associated with the use of aminocarb than with the use of fenitrothion.
6. It is recommended that, if the use of fenitrothion for spruce budworm control continues, regulatory agencies take into account the fact that EMOFICO researchers find fewer environmental effects with two applications of fenitrothion at 210 g. a.i./ha applied a minimum of 4 days apart than with one application of fenitrothion at 280 g. a.i./ha.
7. * It is recommended that monitoring and research agencies initiate or resume work on:
 - (a) long-term effects of spray operations on pollinators and importance to forest ecological integrity;
 - (b) long-term effects on arthropods with respect to plant competition;
 - (c) impacts of spraying on forest floor arthropods vital to nutrient cycling;
 - (d) effects of the brief pulse of insect knock-down on insectivorous birds;
 - (e) impacts of budworm damage on vertebrate habitat; and

7. (f) review of literature concerning environmental implications of the use of Bacillus thuringiensis.
8. * It is recommended that monitoring and research agencies increase emphasis on studies concerning:
 - (a) easier and less expensive ways of determining insecticide deposits in natural habitats;
 - (b) fate and persistence of pesticide active ingredients, spray adjuvants, and their breakdown products in various components of the environment;
 - (c) acute and chronic toxicological effects of pesticides active ingredients, spray adjuvants and their breakdown products on sensitive indigenous species, with particular reference to the possibility of interactions between formulation components;
 - (d) long-term population changes of indicator species; and
 - (e) stream contamination by insecticides and effects on food chains which may affect growth and abundance of fish
9. * It is recommended that monitoring and research agencies continue studies concerning:
 - (a) monitoring methodologies;
 - (b) the phenomenon of spray drift;
 - (c) long-term effects of insecticides on ecological processes such as biological control of forest pests by parasitic and predaceous insects and spiders;
 - (d) pathways of insecticide toxicity to birds;
 - (e) direct toxicity of insecticides to very young fish; and
 - (f) monitoring of shellfish contamination.

* sequence of listing does not imply order of importance

ROLE AND STRUCTURE OF EMOFICO

EMOFICO, the New Brunswick Committee for Environmental Monitoring of Forest Insect Control Operations, reviews and reports environmental surveillance activities related to spraying in the province to control forest insect pests. EMOFICO also makes recommendations to its members and various agencies.

In this report, environmental surveillance is interpreted as research and monitoring including assessment methodologies and regulatory activities. It should be noted that EMOFICO's role does not include direct assessment of human health hazards or spray efficacy.

EMOFICO is a voluntary association of approximately seventy researchers, managers and regulators, from federal, provincial, university and private organizations. It functions as a committee and is independent of the agencies represented by its members. The affiliations of EMOFICO members are given on page 127.

Committees outside New Brunswick which have a similar purpose to that of EMOFICO include the Comité de Surveillance Ecologique des Pulvérisations Aériennes in Quebec, the Environmental Monitoring Committee of the Newfoundland Department of Environment, and the Environmental Monitoring Committee for Spruce Budworm Spraying in Maine.

Environmental researchers from New Brunswick have input to the following organizations also concerned with environmental monitoring of spruce budworm spray operations:

The New Brunswick Task Force on Long Distance Drift
of Forest Insecticides

This is an interdisciplinary group organized in 1978 by the New Brunswick Departments of Natural Resources and Health to review information concerning spray drift. At present the Task Force is developing drift models and preparing a publication on spray drift.

CANUSA

CANUSA is an international program established in 1977 under a six-year joint Canada-United States agreement. CANUSA is headed by the Chief of the USDA Forest Service, and the Assistant Deputy Minister, Forestry, Environment Canada. Its objectives are to design and evaluate economical, environmentally acceptable strategies to control eastern spruce budworm (Choristoneura fumiferana (Clemens)) and western spruce budworm (Choristoneura occidentalis (Freeman)) and to manage forests susceptible to budworms.

Eastern Spruce Budworm Council, Environmental Committee

ESBC is a consortium of deputy ministers of forest resource departments from eastern North America. The Council identifies problems and co-ordinates research related to spruce budworm infestations and forest management practices used to control them. The Environmental Committee of the ESBC makes recommendations to the Council at large, and is working toward standardization and documentation of environmental monitoring methodologies.

Forest Pest Control Forum

The Forest Pest Control Forum, a national meeting of forest managers, and scientists and administrators involved in environmental surveillance of forest pest control programs, has been convened annually by the Canadian Forestry Service of Environment Canada since 1973. The predecessor of the Forum, was a group known as the Interdepartmental Committee on Forest Spraying Operations (ICFSO).

EMOFICO BACKGROUND

- 1950-1960's - Environmental surveillance was discipline-oriented, sporadic, and needed coordination.
- 1970 - Formation of the Pesticide Ecology Research Group (PERG), an informal organization of researchers working in the Maritime Provinces.
- 1976 - Environment Canada formalized a regional EMOFICO Committee to replace PERG.
- 1978 - Environment Canada relinquished control of EMOFICO to the Province of New Brunswick in response to a need for greater provincial rather than regional emphasis.
 - Responsibility for EMOFICO administration rested briefly with the New Brunswick Department of Natural Resources and Forest Protection Ltd.
- 1978-80 - EMOFICO administration was the responsibility of the University of New Brunswick.
- April 1980 - This responsibility was transferred to the New Brunswick Department of the Environment.

EMOFICO'S OBJECTIVES

EMOFICO serves as a forum for individual scientists to communicate their findings and risk assessment to one another, to

managerial agencies and to the public. It is not the role of EMOFICO or the monitoring scientists engaged in risk assessment to enter into subjective or political judgment of safety. EMOFICO aims to impartially report and interpret scientific results and conclusions from environmental surveillance activities. Federal and provincial governments make the policy decisions regarding health and environmental safety based on information from a variety of sources including EMOFICO.

The aims of environmental surveillance related to forest insecticide spray operations in New Brunswick are:

- (1) to measure the biological impact of forest insecticides on vertebrate and non-target invertebrate fauna and on ecological processes, in the forest, aquatic and other ecosystems; and
- (2) to assess the distribution, persistence, degradation and toxicities of insecticide formulations and their components and breakdown products, and develop methodologies for their accurate detection, identification and measurement.

These aims have been established in response to public and managerial concerns that the side effects of insecticide spraying be identified and assessed, that natural environmental relationships are not unduly upset and that the fate of insecticides be traced. Because natural systems are complex and not well understood, scientists are often limited to making inferences from their sampling results or to predicting possible spray-induced ecological effects on the basis of models or trends.

EMOFICO's terms of reference are:

- (1) to encourage the exchange of environmental monitoring information and the coordination of environmental surveillance activities related to forest insecticide spray operations in New Brunswick;
- (2) to provide technical information and recommendations to government agencies and spray operators concerning environmental safety of forest spraying;
- (3) to review the adequacy of knowledge related to environmental effects of forest spraying, identify gaps, and recommend appropriate action in monitoring and research; and
- (4) to present public reports assessing short and long-term effects of spray operations on the environment and summarizing surveillance activities.

Several requisites for the attainment of EMOFICO's objectives and the objectives of individual researchers are identified here in a working philosophy:

- (a) In view of the pressing social, economic and ecological concerns caused by forest insect pests and their management, it is important that the federal government, particularly through Environment Canada, and Fisheries and Oceans Canada, commit adequate funds for environmental research related to the use of chemical or biological techniques to control such forest insect pests.
- (b) Federal, provincial and private organizations involved in research and monitoring of forest insect control operations should further define and coordinate their roles.
- (c) The national pool of research and monitoring expertise should not be allowed to diminish.
- (d) Environmental surveillance is most effective when operational spray activities are kept as simple as practicable, and areas treated with different spray formulations are spatially separated.
- (e) Early consultation between those testing new spray regimes or techniques and those responsible for environmental surveillance is important so that optimal experimental designs can be developed for studies of non-target effects as well as spray efficacy.

SURVEILLANCE COSTS AND FUNDING

The EMOFICO committee has no budget of its own and does not fund or conduct environmental studies. Its component agencies, however, allocate funds as they see fit according to their own priorities and responsibilities. Researchers function independently and are not responsible to the Committee. They negotiate their own contracts and grants and report their findings primarily to the various funding agencies supporting their research. The research reported represents the disciplinary interests of individual researchers and their supporting agencies.

Support for environmental surveillance in New Brunswick is and has been provided from a number of sources including the National

Research Council, Agriculture Canada, Environment Canada, universities, the New Brunswick Department of the Environment, Forest Protection Ltd., the New Brunswick Department of Natural Resources, CANUSA, Fisheries and Oceans Canada, and Supply and Services Canada.

A PRIMER ON INSECTICIDE ECOLOGY

by

I.W. Varty
Maritimes Forest Research Centre
Canadian Forestry Service
Environment Canada

Appraisal of environmental effects of insecticides involves pre-operational screening of candidate insecticides, measurement of direct toxic effects, tracing of indirect toxic effects, and detection of contaminants and assessment of their toxic properties.

The basic potential hazards from insecticide use are tested and assessed through the registration processes around the world. On an international basis, information is provided by the chemical companies so that regulatory agents may make a judgment of insecticide safety for a prescribed national use-pattern. Agriculture Canada's registration protocols insist on satisfactory evidence from scientific studies of: (a) the toxicity of an insecticide's active ingredient to laboratory mammals, as a guide to effects on people; (b) toxicity to other vertebrate and invertebrate animals (many laboratory-reared species, such as chicken, mallard, honey bees, rainbow trout, earthworms), as indicators of the response of wild fauna of natural and modified ecosystems; and (c) the movement, persistence and breakdown of insecticides in air, soil, water and biota.

The basic research and development of the candidate insecticide typically costs the producing company millions of dollars per marketable product, and usually results in the production of scores of research papers, published or confidential on a need-to-know basis, according to the oft-conflicting demands for open scientific scrutiny and patent protection.

All such toxicological information on susceptibility in the laboratory is only a guide to ecological vulnerability. The real test of an insecticide formulation's safety comes with operational practice, because that is the only way whereby the full scope of environmental variables can be identified. These variables include the target and non-target ecosystems, the weather at spray time and thereafter, spray delivery systems, formulations, drift, misapplications and accidents.

Environmental contamination is an inevitable consequence of insecticide application. The concentration, persistence and mobility of spray deposits in the environment are governed by physical, chemical and biological processes and vary with the innate stability and properties of the chemicals used. Fenitrothion and aminocarb, the insecticides used in New Brunswick, are generally considered non-persistent. They are rapidly degraded by sunlight and other chemical processes in air and water; they are metabolized by animal and plant enzymes, and by microbial action in soil and water; they are redistributed by volatilization, leaching and dispersion in air and water. However the stability of any one insecticide is widely variable in different substrates, from minutes to months, and toxic properties and persistences of some breakdown products are not always well understood.

Contamination per se is only a measure of environmental exposure, not toxicity. Of greater consequence are the biological effects in contaminated habitats. The sequence of such effects can be classed as immediate, short-term and long-term, as defined by Varty (1978):

Immediate effects: the mortality and sublethal response of animals during the period of persistence of residues in biologically significant concentrations; this period is usually from several hours to several days, rarely months, in a given habitat. Toxicity to animals is governed by two factors: susceptibility, the inherent reaction of a species at specified growth stage and physiological state to insecticide poisons in a range of concentrations; vulnerability, the risk of exposure to those residues or aerosols, occasioned by the animal's seasonal and diurnal patterns of behavior.

Short-term effects: the population responses and community interactions in a given habitat from spray day until onset of winter or some other point terminating the annual cycle.

Long-term effects: the influence of immediate and short-term effects on population trends over a period of years particularly when spraying is a perennial or intermittent exercise in a given stand. The annual repetition of a spray treatment by annually altering the seasonal dynamics of a susceptible species, could potentially establish new norms of species abundance and community function; such change may be adverse or beneficial to man's socio-economic interest.

Direct toxic effects are usually "immediate" and "acute" (virulent and fast-acting) but may sometimes be "chronic" (delayed and more subtle). Acute toxicity is quantified in laboratory studies by establishing an LD50 for birds, mammals and terrestrial arthropods, or an LC50 for fish and aquatic invertebrates. This is the lethal dose (ingestion, contact, inhalation) or the lethal concentration (in water) at which 50% of an experimental population die within a stated period (usually 24 or 28 h). It is a simple cause-effect relationship in which the experimental variables are uniform and measured.

In field studies, from experimental or operational applications, the rate of animal kill is usually described as a percentage of the density just before spraying. For spruce budworm, of which the densities are difficult to measure at spray time, the rate of kill is calculated by simple formulae which take account of the normal population decline between the needle-mining second-instar larval stage and the pupal stage. In field studies, simple cause-effect relationships are rarely definable because the ecological circumstances contributing to the vulnerability of a test organism are usually complex and variable in space and time.

Chronic effects, in the short-term category, are usually sublethal and exhibited as abnormalities of behavior. Chronic effects were characteristic of the prolonged exposures to the persistent organochlorine insecticides such as DDT and lindane, and have been linked to animal growth restriction, reproductive irregularities and slower response to predators. Such chronic effects have not been demonstrated for animal populations in nature where fenitrothion or aminocarb have been used.

The indirect toxic effects, in the short-term and long-term categories, may take place through various avenues. Non-lethal ambient concentrations of the insecticide may be concentrated by a resistant organism, then transferred through the food chain to predators. Such biological magnification is characteristic of the persistent organochlorine

insecticides but it is uncommon in the organophosphate and carbamate classes. Another pathway for indirect effects is the disruption of biological control relations, as when the predator or parasite is more susceptible than the pest, or has lower population recuperation than the pest; the end result is the resurgence of the target pest or the promotion of minor pests to major status. A third pathway is the reduction of foraging success of a resource organism, as may be occasioned by the diminution of food supply (insects) for birds or fish. When spraying damages key processes within an ecosystem, community integrity may be disrupted for months or years.

The animals in an ecosystem exposed to pesticides can be considered in three functional classes relative to man's interests:

Resource animals (game, songbirds, sport fish, fur animals, honey bees) are valued for a direct human demand (foodstuff, clothing, recreation, heritage, aesthetics).

Process animals (shrews, frogs, lady beetles, mayflies, and thousands of other less familiar species and groups) play important roles in the web of biological processes (energy transfer, plant competition, biological control, nutrient turnover) which ultimately determine the stability and utilizable productivity of an ecosystem. In forests and streams it is desirable for the process species characteristic of a habitat to be present in appropriate numbers at appropriate seasons. It is assumed that forest management practices such as spraying should not unduly stress such natural community balance.

Pest animals are those process or resource animals whose numbers become excessive in relation to human needs for sustained yield of resources. Chemical control is seldom aimed at pest extirpation because it is unattainable except in limited situations such as greenhouses; it is aimed at damping population abundance so that an acceptable threshold of resource damage is not exceeded. All classes of animals (resource, process and pest) are involved in ecological processes, but the classification serves to identify the impact of the three groups on man's exploitation of nature.

Direct and indirect toxic effects on a species population or on an array of species, can be considered damaging to the environment when they cause short-term or long-term reduction in resource values, a perennial maladjustment of the productive processes in the ecosystem, or a loss of genetic diversity with undeterminable consequences. The observed array of immediate effects of a spray operation - mostly dead insects - is not necessarily indicative of a major stress on the functional integrity of a faunal community. Many animal species, both invertebrate and vertebrate, have such reproductive potential and territorial mobility that populations may rebound to the carrying capacity of the habitat weeks or months after the toxic impact. Other species may require one year, or several, for population recuperation. Both the initial intensity of the impact and the needed interval for population rebound determine the degree of environmental damage. However since science is ignorant of the seasonal and perennial dynamics of almost all animal species and faunal communities, it is not generally feasible to conclude that observed short-term or long-term phenomena (processes or populations) can be linked to insecticide impact on a cause-effect basis. The population dynamics of resource and process animals are influenced by many other, often powerful, natural stresses, such as weather, habitat change, migration, food supply and disease epidemics. Good scientists are reluctant to jump to conclusions beyond the formulation of hypotheses, from measurement of a one-factor change in a multifactor

dynamic system. Moreover, obvious ecological effects do not necessarily equate with environmental damage.

The literature on forest spraying (Prebble, 1975) suggests that, typically, the observed ecological effects from current insecticide practices in eastern Canadian forests are short-lived and readily absorbable within ecosystem dynamics. The pesticide dosages used are low, the frequency of use is low, and there are long intervals for population recuperation through immigration and on-site reproduction. The target budworm population itself is the clearest indication of insect capacity to rebound quickly after drastic knockdown of its immature forms. The records of sharp ecological upsets and of identified environmental damage in the 1970's are scarce, notwithstanding the accumulated spray coverage of tens of millions of hectares in eastern Canada since 1969. The general record from environmental surveillance, in the last decade, is mainly a collection of statements of a lack of significant effects in the vertebrate fauna and of little long-term impact on the invertebrate fauna. The identified risks from the current forest protection tactics are perceived to be low by most environmental monitoring agencies.

Scientific caution is based not so much on the observed events, but on its assessment of the capability of the monitoring process. The doubting questions are valid. Is it possible, with the present rate of commitment of money and expertise, to detect the variability of biological events in a provincial spray program that covered 3.8 million ha in 1976, or even the 1.5 million ha in 1978? Is it possible to adequately observe dozens of sprayed ecosystems and scores of specific faunal habitats, or to monitor populations of scores of species of vertebrate animals or thousands of species of invertebrates? Do biologists know enough about ecological and chemical processes to be able to detect dysfunction? Broadly the answer is no; monitoring agencies do not have that capability in depth. They acknowledge some lack of survey breadth, sampling depth, subdisciplinary expertise, and proven methodologies; they lack funds. In the background there are inadequate baselines for species populations, and in the foreground inadequate control of operational and experimental parameters. Environmental monitoring is a new branch of science and there is no deep international well of experience to draw upon. Moreover, biological uncertainties are inherent and cannot be eliminated by more time, manpower and money (Holling, 1977). Thus, in broadcasting poisons around the landscape, even at low concentration and brief persistence, the proponent takes risks which cannot be precisely monitored or predicted. Such a risk-taking attitude is hardly unique to forest managers; rather it is mankind's universal experience.

Environmental surveillance of the spray operations is founded on a simple concept of quantifying animal abundance and chemical concentrations and distributions; values are compared before and after the spray application in the same block; and sprayed and untreated sample plots are compared contemporaneously. Monitoring is based on periodic inventories by surveys with severely restricted sampling capability. For economy of effort, monitoring agencies choose species which are easier to sample as indicators for the fauna in general, and select habitats which are most exposed to contamination as worst-case indicators for all the others.

Monitoring practice is largely intuitive and trial-and-error in characteristic; it is only beginning to develop cause-and-effect experimentation and model ecosystem methods, but essentially at this time it

is largely descriptive with little predictive capability (NRCC, 1977; Varty, 1977). This conforms with the general state of the art in macro-scale ecology; damage has to occur before process dysfunction is detected. Scientists are aware of what is technically needed for impact assessment: the major building blocks are models of integrated systems and species population dynamics, knowledge of toxic pathways and contaminant sinks, knowledge of the linkages of chemical and biological processes and an understanding of ephemeral change and ecosystem resilience. In relation to forest spray practices, the evidence of damage and the perceived risks have not been large enough to compel a more rapid development of predictive capability, or an understanding of the limits of predictability.

Moreover, at the resource management level, governments across Canada have difficulty in formulating forest policies and defining objectives, given the imperfect inventory of baseline knowledge and uncertain industrial and social demands in the future. It is fair to say that in no province are there policies aimed at optimizing multiple-use forest productivity based on scientific knowledge of habitat dynamics. These observations are offered not in a sense of criticism of forest trusteeship or of science direction, but only to acknowledge that monitoring is part of an undeveloped resource management framework, and that we have a long way to go in resource conservation and sustained yield.

The critical problem is the definition of "deleterious effects" or "environmental damage", and it is my personal opinion that at our present stage of sophistication in pesticide ecology, scientists can rarely arrive at a perception of proven damage to resources or processes in the forest and associated environments. Ecologists generally make the basic assumption that what is natural is most efficient (in terms of energy conversion, biomass production). But what nature does best, is not necessarily in our human short-term or long-term best interest. For a hypothetical example let us suppose that one km of stream has a stocking of 500 yearling trout, the presumed carrying capacity of the habitat. But it is reasonable to hypothesize that a smaller number of yearlings - say 100 per km - would grow much faster within the limits of the total food supply, and might produce more 25 cm trout (the sportsman's objective) within a given time, with sustained yield. In those circumstances, a thinning of the immature crop - by whatever means - might be an appropriate management technique. Such thinning practices are common in all kinds of crop husbandry. While this example has no substance in itself, it is meant to illustrate the point that insecticidal kill of resource organisms cannot automatically be judged as environmentally deleterious particularly given that biologists and managers have considerable difficulty assessing the carrying capacity of a habitat, or of determining the optimum density which integrates habitat productivity and management objectives.

The problems of environmental monitoring of spray programs are only part of the greater issue of forest and stream resource management. New Brunswick has been forced by its persistent budworm problem to develop new scientific capability and management flexibility, and in some respects, is in the forefront in forest resource expertise, including insecticide ecology.

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A SYNOPSIS OF RESULTS OF BUDWORM SPRAYING

IN NEW BRUNSWICK IN 1980

by

E.G. Ketella

Maritimes Forest Research Centre
Canadian Forestry Service
Environment Canada

The predominant factor affecting the conduct of the spray program in 1980 was weather. For the past two years very unusual weather conditions have prevailed prior to and during the spray operations. In 1980, the month of April was extremely warm and rapid development of trees and early emergence of spruce budworm larvae occurred. However this weather trend changed and the months of May and June were decidedly cool. The cool weather retarded spruce budworm larval development but enhanced the growth of fir and spruce shoots thus exposing spruce budworm larvae and increasing the effect of the sprays. Unlike 1979, the phenological zones in New Brunswick in 1980 remained intact, facilitating the orderly conduct of the spray program and the application of two doses of insecticide to most of the area (see Fig. 1).

Area Sprayed

Spray operations conducted by Forest Protection Limited (FPL) in 1980 covered about 1,614,000 ha. Two insecticides and three types of aircraft were used in the operations (Table 1). The largest area (1,317,000 ha) was treated with fenitrothion from TBM (Grumman Avenger) aircraft. Spray operations commenced on 24 May and ended on 20 June 1980.

Results of Spraying

a) In general, the results of the 1980 spray program were rated as good to excellent, with some minor exceptions. The percentage of foliage saved was higher than in the past two years. Examination of the maps of spraying and defoliation shows just how effective the 1980 program was. Of the 673,000 ha of moderate to severe defoliation recorded in New Brunswick only 93,000 were inside the treatment area (Table 2). On closer examination most of this defoliation inside the spray area coincided with those areas over which FPL was required to shut off the spray booms.

b) Similar foliage protection was obtained with both insecticides, Matacil^R and fenitrothion.

c) The degree of protection was similar on balsam fir and spruce.

d) There was no significant difference in foliage protection between areas treated with TBM or Thrush Commander aircraft.

e) The results of spraying in block 24 (which was initially removed from treatment and then placed back in the operation) were variable and reflect the single treatment with B.t. over part of the area and fenitrothion over part of the area, as well as the late timing of the treatment.

Results of Defoliation Surveys

A cooperative aerial survey to map the nature and extent of spruce budworm defoliation (Fig. 2) involved personnel of FPL, the Department of Natural Resources (DNR) and the Maritimes Forest Research Centre (MFRC). About 849,000 ha of defoliation were identified in New Brunswick of which about 673,000 ha were classified in the moderate to severe categories. About 93,000 ha of moderate to severe defoliation were identified inside the boundary of the spray area. The amount of defoliation recorded in 1980 was considerably less than that recorded in 1979 and reflects the forecasts of a year ago and the results of the spray operation.

Results of Surveys for Egg-mass Infestations and Hazard

As the result of a meeting between representatives of DNR, FPL and MFRC, a major re-location of egg-mass sample points took place. In the past about 45% of the sample points were located in the "one mile set-back zone." Most of these were re-located inside the zone of protection and it is hoped this has enhanced our accuracy in predicting infestations and hazard in the protection zone. A map was prepared showing areas of moderate to high hazard and moderate to high egg-mass infestation inside the zone of protection (Fig. 3). In all, about 1,500,000 ha inside the protection zone are in a moderate to high hazard category and an additional 1,100,000 ha have low hazard but moderate to high egg-mass infestations. Examination of the map shows that the areas of hazard and egg infestation are concentrated in the northern half and west-central regions of the province. Essentially, there has been an increase in the extent and intensity of egg-mass infestations in the western and northern regions of the province similar to increases in infestations in adjacent areas of Quebec. Most of the increases in infestations are located in forest areas not treated in 1980 and reflect the general high survival of budworm in non-treated areas.

Experimental Spraying

Operational Trials with *Bacillus thuringiensis* (B.t.): An operational-experimental program with B.t. was conducted by FPL to assess the feasibility of using B.t. in the prevention of spruce budworm damage in woodlots. Over 150 woodlots were examined for pre- and post-spray populations of budworm and resultant damage. Analysis of the data shows no clear difference in performance between the three spray systems used

(fixed-wing aircraft with boom and nozzle, fixed-wing aircraft with Micronair nozzles, and helicopter with boom and nozzle). Further, only about one-third of the blocks treated received visibly adequate protection, one-third received marginal protection and one-third received no visible protection. This fits into the general result pattern of B.t. and was expected.

Trials with Low Drift Materials and Fenitrothion: A series of 40.5 ha blocks were treated each with one application of fenitrothion. One-half was treated with fenitrothion emulsion alone and one-half with fenitrothion emulsion and an anti-drift agent. Two spray systems were used in each set: boom and nozzle equipment and Micronair spray nozzles. The results show no real difference between any of the treatments and in fact all treatments offered only marginal protection to the forested areas sprayed. This is probably a direct result of the small size of the areas treated and the low volume of spray used per unit of land.

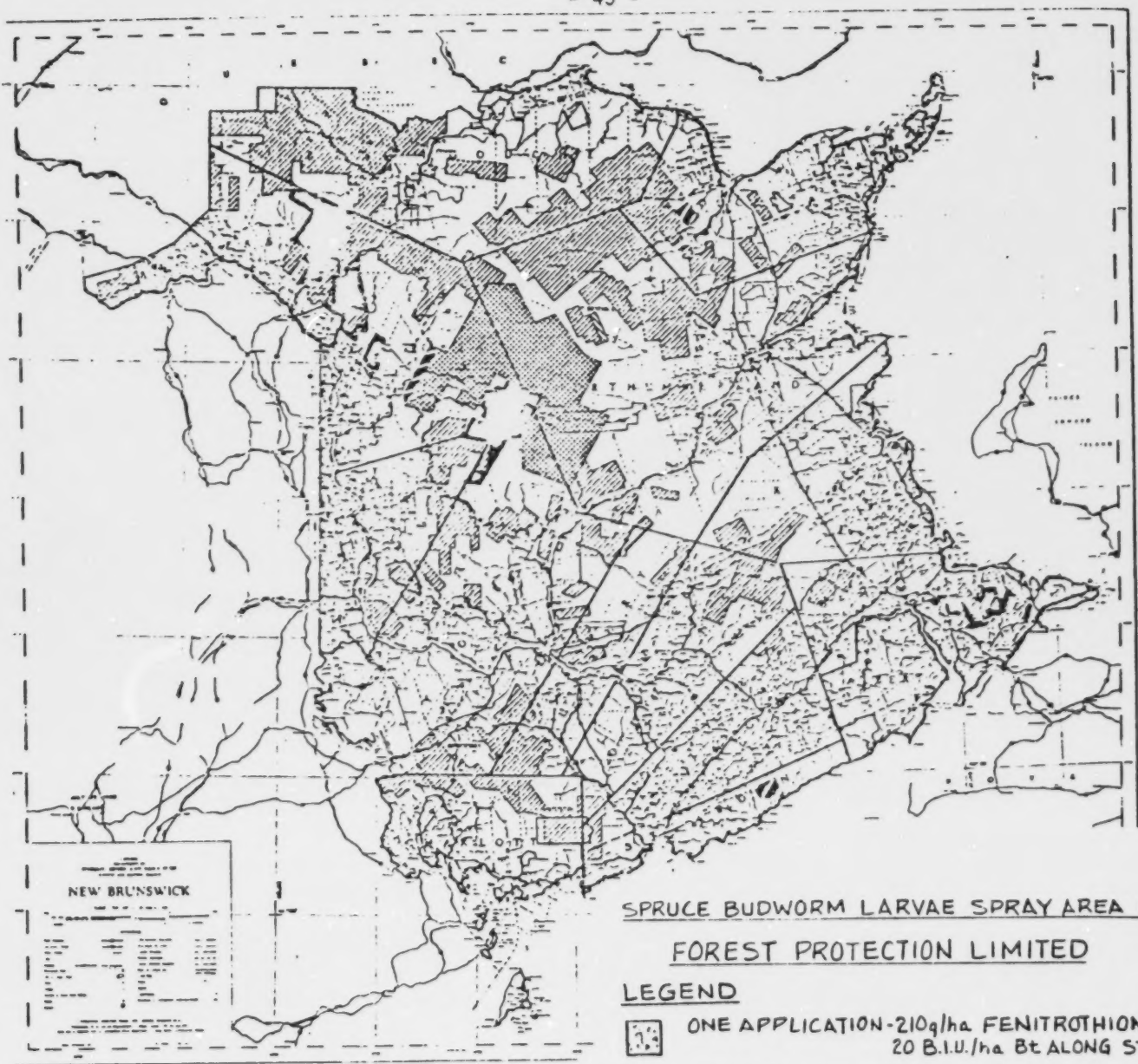


**FIG. 1. AREAS OF NEW BRUNSWICK
SPRAYED FOR SPRUCE
BUDWORM LARVAE IN 1980
(COURTESY OF FPL)**



FOREST PROTECTION LIMITED
AERIAL SURVEY FOR CURRENT DEFOLIATION - 1980

LEGEND

- - MODERATE TO SEVERE
- - LIGHT TO MODERATE
- - NIL OR LIGHT PATCHY

FIG. 2. AERIAL SURVEY OF NEW BRUNSWICK FOR
CURRENT DEFOLIATION BY SPRUCE BUDWORM
IN 1980 (COURTESY OF FPL).

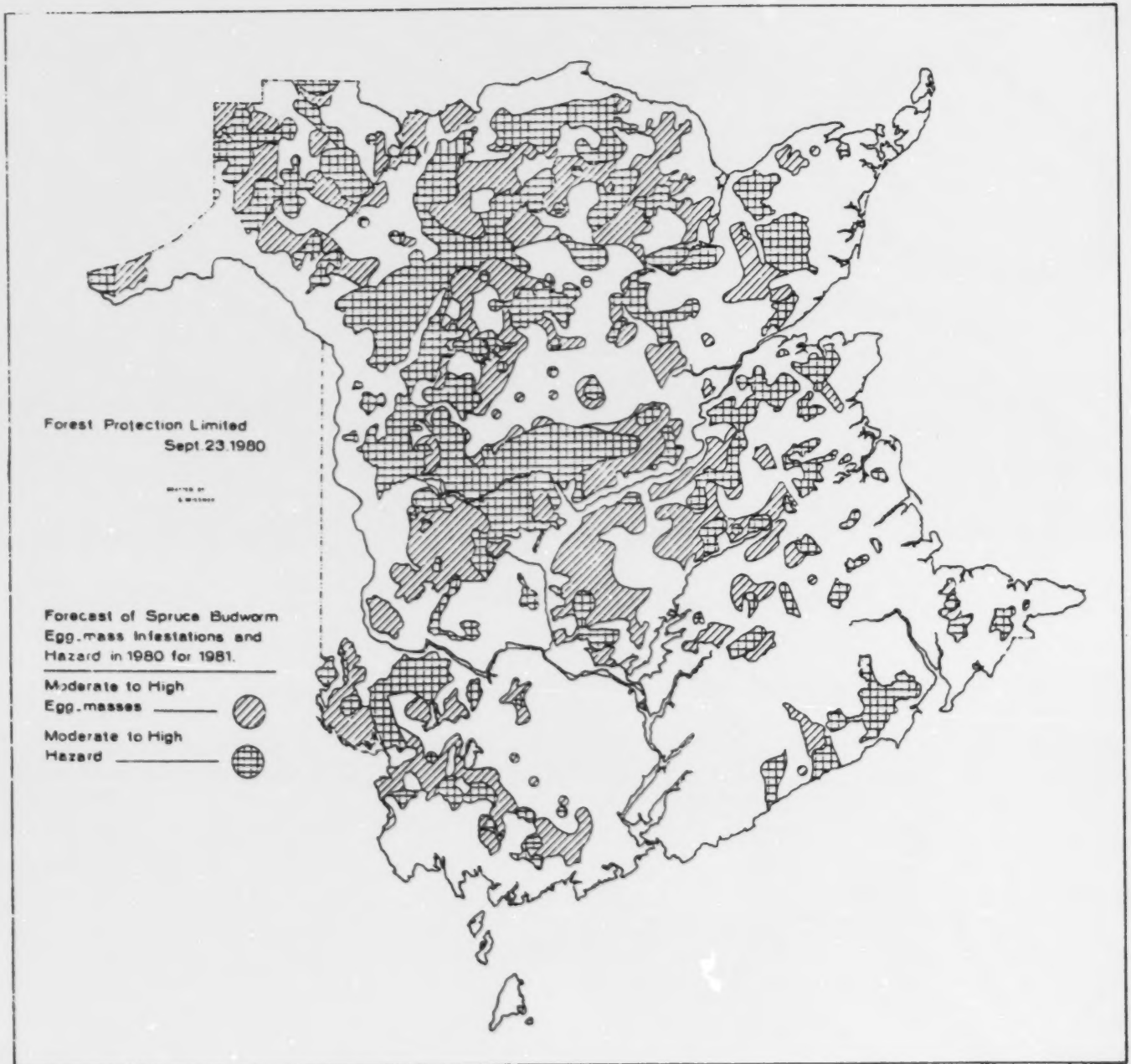


Fig. 3. Area of egg-mass infestations and hazard forecast in 1980 for 1981 (courtesy of FPL).

Table 1. Operational Spray Area, 1980 (hectares x 1000)

Treatment	Area Sprayed
<u>One Application</u>	
(A) 210 g a.i./ha fenitrothion - TBM	8
<u>Two Applications</u>	
(B) 1. 210 g a.i./ha fenitrothion - TBM 2. 210 g a.i./ha fenitrothion - TBM	1317
(C) 1. 210 g a.i./ha fenitrothion - Thrush* 2. 210 g a.i./ha fenitrothion - Thrush	36
(D) 1. 70 g a.i./ha Matacil ^R - DC-6 2. 70 g a.i./ha Matacil ^R - TBM	123
(E) 1. 70 g a.i./ha Matacil ^R - DC-6 2. 70 g a.i./ha Matacil ^R - DC-6	127
(F) 1. 210 g a.i./ha fenitrothion - TBM 2. 70 g a.i./ha Matacil ^R - TBM	3
Total	1614

* Thrush areas were sprayed by Forest Patrol Limited under contract to Forest Protection Limited.

Table 2. Summary of spruce budworm defoliation in New Brunswick from 1978 to 1980 (hectares x 1000).

Defoliation category	Year			
	1978	1979	1980	
			Total province	In sprayed area
light	141	105	176	46
moderate	219	235	226	49
severe	450	1085	447	44
total moderate and severe	669	1320	673	93
total all categories	810	1425	849	139

OVERVIEW OF FOREST PROTECTION OPERATIONS
AND SPRUCE BUDWORM SURVEYS IN NEW BRUNSWICK, 1981

by

E.G. Ketella
Maritimes Forest Research Centre
Canadian Forestry Service
Environment Canada

In this section, the efficacy of spray operations conducted by Forest Protection Ltd. (FPL) in 1981 to provide foliage protection from spruce budworm feeding in selected areas of forest in New Brunswick is reviewed and spruce budworm infestation levels and tree hazard for 1982 are forecasted.

Treatment areas were selected by the Department of Natural Resources (DNR), using the egg-mass infestation and hazard map (Fig. 3 in the previous section) as a guide, in consultation with the forest industry, FPL and the Maritimes Forest Research Centre (MFRC). Assessments of the results of spraying and forecasts of infestations and hazard are based on information gathered by field and laboratory personnel of FPL under the supervision of MFRC.

Area Sprayed

Spray operations (Fig. 1) conducted by FPL covered about 1,900,000 ha. Included were 30,000 ha of private woodlots in what was once referred to as the "one mile set-back zone." Spraying in this area was limited to small agricultural-type aircraft. A synopsis of all the areas treated, by dosage and aircraft type, is shown in Table 1. A new type of aircraft, the M-18 (manufactured in Poland), was used on the project and the small area in which they were used was listed in areas treated by TBM's. The insecticide fenitrothion was used at a dosage of 210 g a.i./ha per application.

Spray operations commenced on 19 May and ended on 20 June. About 116,000 ha in the large-scale operation received only one application at the recommendation of Canadian Forestry Service (CFS) because of low budworm populations remaining after the first application. About 3,000 ha in the private woodlot operation received only one application because the second application would have been too late to provide any further foliage protection.

Results of Spraying

The effectiveness of spraying is evaluated from:

- 1) extensive aerial surveys of current defoliation, and
- 2) from intensive surveys for pre-spray larvae, post-spray pupae and defoliation in treated and control plots.

The results of egg-mass surveys are not used to evaluate spray efficacy. Such surveys reflect the population level of the next year's infestation, usually the result of many factors other than spraying. Spray operations, such as the one in New Brunswick, are only crop protection tools, conducted to save foliage not eradicate insects and are carried out over only a portion of the general area infested by the pest insect. As a result, they have little influence over the general population trends of widespread infestations such as the present budworm epidemic.

Large-Scale Operational Spraying

Operations were affected to some degree by "bad" spray weather particularly in north-western New Brunswick. Nevertheless, protection was generally good to excellent. An average of 50% of the foliage crop that would have been lost in 1981, if it was not sprayed, was saved and survival of budworms was less than 5%, compared to a survival rate of 25% in the non-treated areas. Analysis of aerial surveys of defoliation shows that only 17% of the treated area received a detectable level of defoliation (Table 2). A significant portion of this defoliation coincided with areas along water courses over which spray personnel were required to shut off the spray booms. No differences in spray efficacy were detected between aircraft types and, in general, areas treated twice had a higher level of protection than areas treated once.

The 1981 results were very similar to those obtained over the past six years and confirm the effectiveness of fenitrothion in such a crop protection program.

Protection to Private Woodlots

The spraying of small woodlots was also affected by bad spray weather, but assessment of 29 of the 105 woodlots treated in the one mile buffer zone showed acceptable levels of protection in 26 (or 90%) of the woodlots sampled. This is a significant increase in protection over the 1980 B.t. spray program when only 35% of the areas treated received adequate protection. However, in two areas of the province, one west of Fredericton, the other in Madawaska County, the level of foliage protection was somewhat less because of the lateness of the second application of insecticide.

Results of Defoliation Surveys

A cooperative aerial survey to map the nature and extent of spruce budworm defoliation (Fig. 2) was conducted by personnel of FPL, DNR, and MFRC. About 1,374,000 ha outside and within the treated areas were classified as moderate to severe defoliation, which is an increase over

1980 when 673,000 ha of moderate to severe defoliation were detected. This increase in defoliation was predicted from the 1980 egg-mass survey.

Only 268,000 ha of the moderate to severe defoliation were recorded inside the general boundary of the 1981 spray program.

Forecast of Infestations and Hazard for 1982

In 1981, 1,722 locations in New Brunswick were sampled for spruce budworm egg-masses and hazard to trees. This was a significant increase in the level of sampling over 1980 when 1,200 locations were sampled. The increase in sampling was done at the request of DNR to ensure that the "buffer" zones were sampled adequately.

The results of the egg-mass survey (Fig. 3) show that there were moderate to high infestations in all sectors of the province (Table 3) and that in five of the six regions egg-mass infestations are higher in the "buffer" zone than in the protection zone. Further, 1981 infestation levels in the "protection zone" were significantly higher than the 1980 levels in the eastern half of the province, about the same in the north and central west sectors, and substantially lower in the southwest sector (Figure 4). Continuing moderate to severe budworm infestations over most of the forest area of New Brunswick are forecast for 1982.

Hazard ratings are based on forecasts of infestation and on the past and current history of tree damage. The map (Fig. 3) is based on information gathered during egg-mass surveys and aerial surveys of defoliation. Most of the forests in the protection and buffer zones are generally in moderate to high hazard rating due primarily to the increase of infestations and the amount of defoliation in 1981.

In many respects the current situation in the forest parallels that of 1974. An insufficient control effort in 1975 resulted in a very serious decline in the health of the forest. Similarly, if the forest is allowed to deteriorate in 1982 because of budworm feeding, extremely severe defoliation is almost a certainty for 1983 leading to extensive tree mortality in 1984.

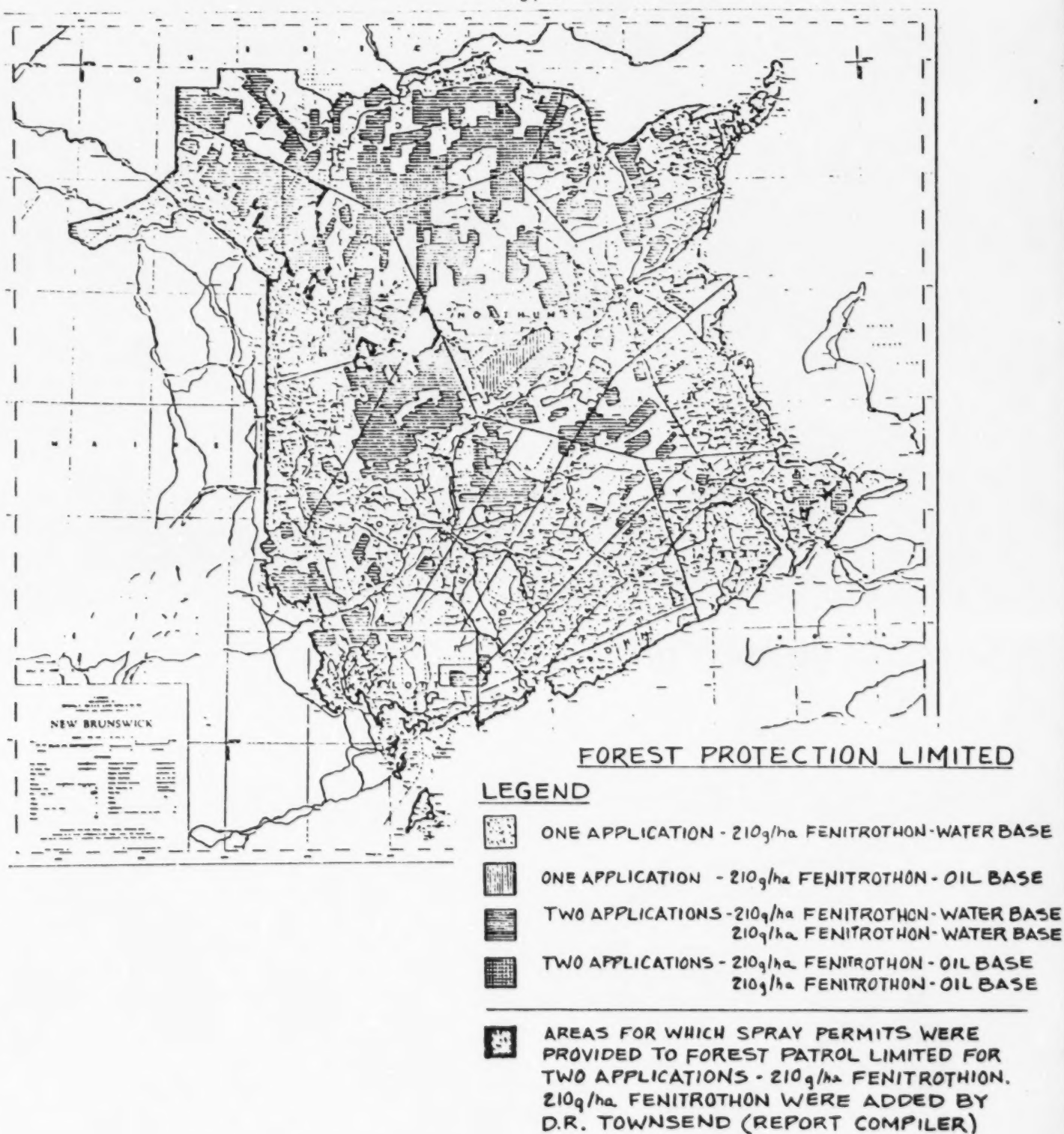


FIG. 1. AREAS OF NEW BRUNSWICK SPRAYED FOR SPRUCE BUDWORM LARVAE IN 1981.



FOREST PROTECTION LIMITED
AERIAL SURVEY FOR CURRENT DEFOLIATION - 1981

LEGEND

-  - MODERATE TO SEVERE
-  - LIGHT TO MODERATE
-  - LIGHT & PATCHES OF LIGHT
-  - NO DETECTABLE DAMAGE

FIG. 2. AERIAL SURVEY OF NEW BRUNSWICK FOR
CURRENT DEFOLIATION BY SPRUCE BUDWORM IN 1981

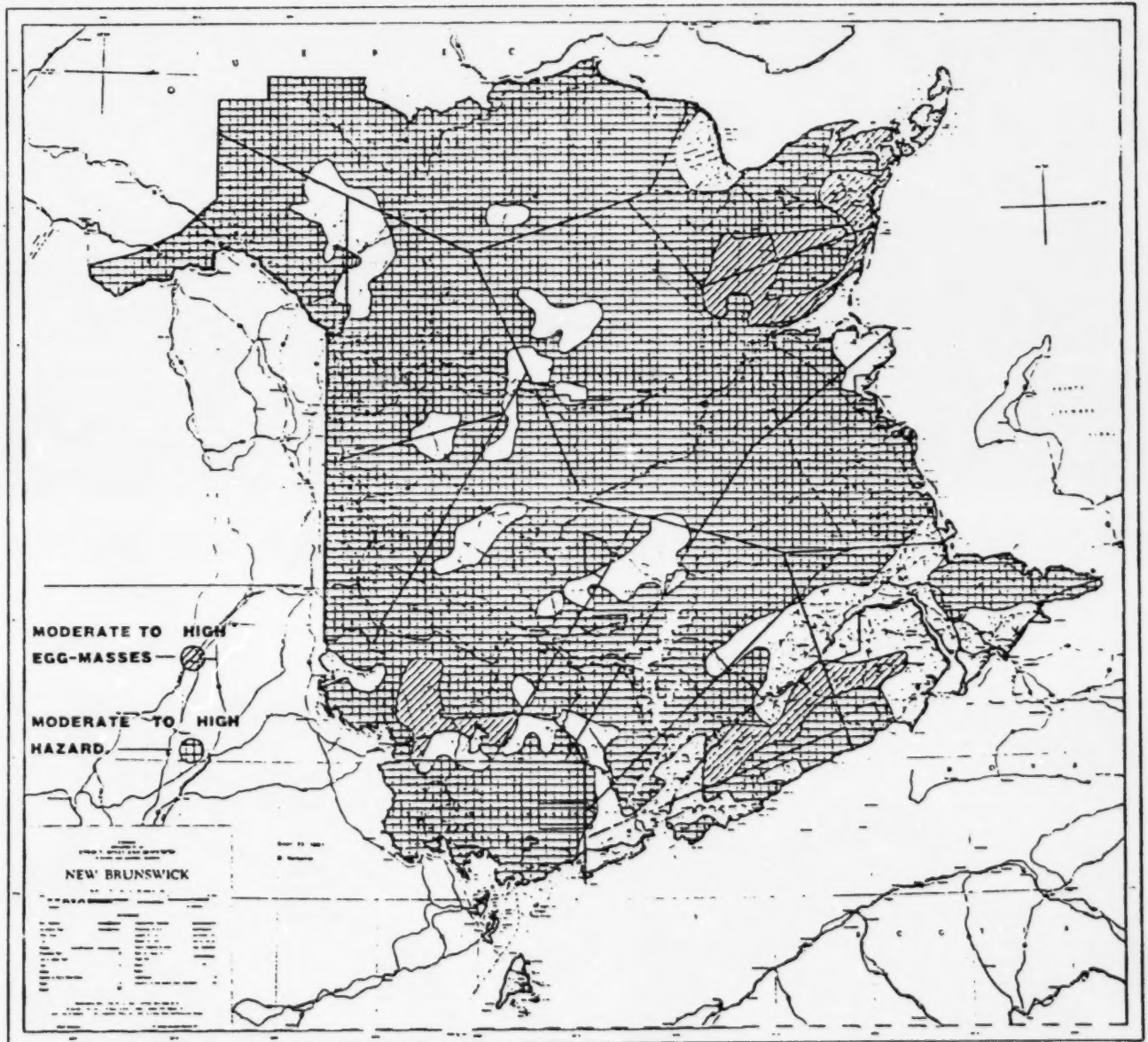


Fig. 3. Area of egg-mass infestations and hazard forecast in 1981 for 1982.



Fig. 4. Sectors of New Brunswick.

Table 1. A synopsis of the area sprayed in 1981 by Forest Protection Ltd., by dosage, application rate, aircraft type and carrier.

<u>Operational</u>	<u>Hectares</u> <u>thousands</u>	<u>Aircraft</u> <u>Type</u>
<u>One Application</u>		
(a) 210 g a.i./ha fenitrothion in 239 ml/ha - water base	70	TBM-3
(b) 210 g a.i./ha fenitrothion in 239 ml/ha - oil base	46	DC-6
<u>Two Applications</u>		
(c) 210 g a.i./ha fenitrothion in 239 ml/ha +210 g a.i./ha fenitrothion in 239 ml/ha water base	1481	TBM-3
(d) 210 g a.i./ha fenitrothion in 239 ml/ha +210 g a.i./ha fenitrothion in 239 ml/ha - oil base	222	DC-6
(e) 210 g a.i./ha fenitrothion in 119.5 ml/ha +210 g a.i./ha fenitrothion in 119.5 ml/ha - oil base	51	Thrush ¹
TOTAL	1870	
<u>Private Woodlots</u>		
<u>One Application</u>		
210 g a.i./ha fenitrothion in 239 ml/ha - oil base	3	Ag-Cat Ag-Truck Pawnee
<u>Two Applications</u>		
210 g a.i./ha fenitrothion in 239 ml/ha +210 g a.i./ha fenitrothion in 239 ml/ha - oil base	27	Ag-Cat Ag-Truck Pawnee
TOTAL	30	
GRAND TOTAL	1900	

¹Thrush areas were sprayed by Forest Patrol Limited under contract to Forest Protection Limited.

Table 2. Spruce Budworm Defoliation in New Brunswick from 1978 to 1981 (hectares x 1000)

Defoliation Category	1981	
	Total Province	In Sprayed Area*
Light	137	52 (38%)
Moderate	388	104 (27%)
Severe	849	164 (19%)
TOTAL ALL CATEGORIES	1374	320

* The area treated in 1981 by Forest Protection Limited was 1.9 million ha. Some 320,000 ha of defoliation were detected in the treated area which means that 83% of the area treated had no detectable level of defoliation.

Table 3. Summary of Mean Spruce Budworm Egg-mass Infestations In Six Regions of New Brunswick

REGION	1981 MEAN EGG-MASS INFESTATION (egg-masses/10m ²)		1980**
	Set Back Zone	Protection Zone	
North West	429 (46)*	245 (358)	223
North East	457 (55)	361 (155)	168
Central West	278 (93)	220 (222)	234
Central East	409 (113)	302 (206)	197
South West	211 (149)	142 (115)	215
South East	187 (128)	251 (81)	155

* no. of sample points ()

** set back zone - not sampled in 1980, so 1980 figures apply to protection zone only.

WILDLIFE

THE MANAGEMENT PERSPECTIVE

by

J. C. Baird

Fish and Wildlife Branch
New Brunswick Department of Natural Resources

Birds and mammals are important resources and in New Brunswick most are products of a forest environment. The abundance and diversity of wildlife are dependent on habitat. The condition of forest stands and the strategy employed to manage the spruce budworm problem have a bearing on wildlife populations because habitat is affected. Beyond the habitat aspect, the use of insecticides has the potential to influence wildlife populations through direct mortality or through sub-lethal effects on behavior or physiology which may result in reduced wildlife production. Decisions on forest spray operations must take these factors into account.

It is the responsibility of government to respond to public concern. Information helpful to wildlife agencies is often provided by the public. On the other hand unfounded expressions of concern may result in pressure on government to support monitoring exercises of little significance to resource conservation.

Differences in the properties of insecticides and the attributes of spray regimes must be considered when monitoring and research needs are identified and addressed. For example, the persistence and biological magnification of DDT presented a different set of needs compared to fenitrothion and aminocarb which are non-persistent. Monitoring and research needs must also be judged in light of our experiences and the results of investigations by others.

Other circumstances have a bearing on an assessment program related to wildlife. Populations are dynamic and numbers may fluctuate widely from season to season and year to year. Many species are characterized by large and rapid turn-overs in populations each year. The loss of individuals often does not exert a significant influence at the population level. Also, events that occur far from New Brunswick can affect populations of migrating birds that spend part of the year in our Province. One must appreciate the dynamics of populations and the range of factors that may be involved to achieve the management perspective.

Some information which wildlife management agencies collect concerning the status of wildlife populations is not directly related to an assessment of budworm spray operations. Data and trend analysis of breeding populations, production and harvest rates are key elements within management programs. Increased emphasis on such on-going surveys may facilitate the assessment of the relationship between spray operations and the status of wildlife populations. Monitoring and research needs cannot be met by a wholesale substitution of that approach but cost efficiencies and an improved ability to respond to specific public concerns could be realized.

MIGRATORY SONGBIRD ASSESSMENTS

by

P. A. Pearce

Canadian Wildlife Service
Environment Canada

Within the forest ecosystem, areas targeted for spraying and non-target areas provide the habitat requirements for about one hundred species of birds, two-thirds of them songbirds. The vulnerability and individual susceptibility of birds to stress posed by exposure to applied chemical insecticides varies widely. Most of the forest birds are migratory and thus constitute an international resource for the protection of which there are important national responsibilities. In the past few years, monitoring - in the sense of extensive surveys to identify possible spatial and temporal changes in populations - revealed no intolerable impacts on songbirds of budworm suppression tactics. During the last two years, no such monitoring was deemed by the spray proponent to be necessary and none was undertaken.

With regard to research, various components of studies of the ingestion toxicity of fenitrothion and its influence on aspects of the behavior, physiology and reproduction of the white-throated sparrow, potentially a good indicator of spray effects, began to fall into place. It was determined that the minimum impact of fenitrothion spraying was a small reduction in the rate of nestling growth and in fledging weights but implications for the survival of such disadvantaged fledglings remain unclear. In contrast, in areas subjected to experimental overdosing through superimposition of spray swaths, mortality of adults and nestlings and severe reduction of reproductive success occur. It is now possible to set these findings, and those of research elsewhere, in the context of operational fenitrothion spraying in New Brunswick, with its history of sporadic mortality of songbirds. The threshold of acutely toxic effects, including lethality to susceptible individuals of the most vulnerable species of songbirds, appears to lie at between 210 and 420 g a.i./ha. Clearly, in terms of immediate effects, the margin of safety is narrow: where inadvertent overdosing occurs (e.g., through overswathing resulting from non-maintenance of the integrity of spray aircraft formation, or imprecision in emission tract re-alignment) undesirable impacts on songbirds can be expected. Information on the toxicity of aminocarb (the registered product Matacil 1.8D) at the prescribed dosage rate suggest that it would not likely be hazardous to songbirds and, indeed, in monitoring surveys in the past several years few untoward effects on songbirds were noted where aminocarb was applied (e.g., Pearce & Garrity, 1981). It is concluded that in the New Brunswick operational spray context and in terms of the immediate hazard to exposed songbirds, aminocarb is preferable to fenitrothion at currently prescribed dosage rates.

Determination of tissue cholinesterase activity using standard techniques employed internationally has proved to be valuable in assessing the total exposure of songbirds to forest sprays and has facilitated valid comparison of the results of different investigations. The most appropriate application of tissue cholinesterase determinations is in the measurement of the response of potentially vulnerable birds (e.g., some warblers which live in the tree canopy) in small-scale, controlled field tests of new cholinesterase-inhibiting insecticides, or of more familiar ones in new formulations. There will be a continued need for assurance that developments in insect suppression technology using chemicals pose no unacceptable hazard to wildlife before their adoption in wide-scale operational spray programs.

Recent research carried out in New Brunswick should contribute to a much-needed identification of the method or combination of methods most effective for monitoring the short-term impact of operational, or experimental, spray programs on songbirds. Monitoring methodology could include one or more survey techniques, observation of captive birds in spray zones, mark-recapture techniques, and studies of nesting success. Intensive investigation of key indicator species could be especially valuable. Determination of the long-term influence of the protection strategy on birds is important but remains as problematical as ever. Forest condition, management practices other than the use of chemicals, ecological succession, the size of populations of budworms and other insects - all may play a role in governing populations of forest birds in the province, as may environmental stresses imposed during migration and while birds are on the winter range. Such factors will undoubtedly continue to challenge attempts to attribute shifts in songbird populations in New Brunswick to provincial spray practices.

REFERENCE

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BRAIN CHOLINESTERASE RESPONSE IN SONGBIRDS

EXPOSED TO EXPERIMENTAL FENITROTHION

SPRAYING IN NEW BRUNSWICK

by

D.G. Busby, P.A. Pearce, and N.R. Garrity
Canadian Wildlife Service
Environment Canada

Continued spruce budworm (Choristoneura fumiferana) infestation of the fir-spruce forest of eastern Canada has been accompanied by a constant search for control strategies that are effective, environmentally acceptable, and that pose no threat to human health. Testing of the efficacy and safety of new chemicals, old chemicals in new formulations, and the development of spraying technology have been important elements in New Brunswick's approach to management of the budworm problem.

Determination of songbird responses to experimental spraying provides a preliminary indication of the hazard of a particular spray regime prior to adaption to full-scale operational spraying.

In line with CWS intent to assess the hazard to forest passerines of new forest spray chemicals, and old ones in new guises, bird responses were measured during low-drift fenitrothion efficacy spray trials conducted by FPL. Exposure was assessed by determination of brain cholinesterase (ChE) activity in four species of warbler and in the white-throated sparrow. Spray was applied as an emulsion by Cessna 188 Ag-Truck using boom and nozzle and rotary atomizer equipment. The formulation (including a particulating agent) was sprayed at 280 g active ingredient in 4.67 L of emulsion/ha. ChE inhibition was evident in all species investigated. Of 114 birds from spray blocks, 27 and 5 showed ChE depression of more than 20% and 50%, respectively. The greatest ChE reduction, in a white-throated sparrow, was 59%. ChE inhibition exceeding 20% is believed to be indicative of exposure to a ChE-inhibiting chemical, and more than 50% to be sufficient for attributing death of a bird to the insecticide. We found no dead birds or evidence of aberrant behavior. Our research elsewhere (manuscript in preparation) showed no avian mortality associated with 15-20% inhibition, and death of 20% of free-living, adult white-throated sparrows was associated with a mean ChE reduction of 42% when the birds were exposed to fenitrothion spraying. In the present study, use of boom and nozzle and rotary atomizer spraying did not result in any consistently different impacts: however, interpretation of results was difficult because of the possible confounding effects of other factors such as time of spray application.

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Busby, D.G., P.A. Pearce, and N.R. Garrity. 1981. Brain cholinesterase response in songbirds exposed to experimental fenitrothion spraying in New Brunswick, Canada. Bull. Environ. Contam. Toxicol. 26: 401-406.

BRAIN CHOLINESTERASE RESPONSE IN SONGBIRDS

EXPOSED TO EXPERIMENTAL AMINOCARB SPRAYING

IN NEW BRUNSWICK

by

D.G. Busby, P.A. Pearce, and N.R. Garrity
Canadian Wildlife Service
Environment Canada

This study was carried out in the context of a series of spray trials of a new formulation of aminocarb known as Matacil^R 180 Flowable, conducted by FPMI primarily to determine efficacy against spruce budworm. The trials were of particular interest to us. Although measurement of brain cholinesterase (ChE) has been widely adopted as a useful tool in determining exposure of birds to organophosphate and carbamate insecticides, there is little published information on the effects of aminocarb on ChE in forest songbirds. Also, the logistical problems normally encountered in monitoring bird responses under operational spraying conditions were minimized by the small scale of the project.

Bird exposure to spraying was assessed by determination of brain ChE activity in five species of warblers: blackburnian warbler, an upper canopy dweller; Tennessee and bay-breasted warbler, mid-to-upper canopy dwellers; yellow-rumped warbler, a species occurring at all levels in the canopy; and American redstart, a lower canopy dweller. ChE activities of birds collected in sprayed forest were compared with ChE activities of birds from unsprayed forest, a statistically significant decrease being considered as a detrimental impact. The study plots were located in fir-spruce forest about 25 km west of Bathurst, N.B. Each was 50 ha in area and was sprayed by a Cessna 188 Ag-Truck fitted with four Micronair AU3000 rotary atomizers. The plots were sprayed at a stated emission dosage of 70 g a.i./ha. By volume, the formulation consisted of 25.93% Matacil^R 180F, 1.27% Atlox^R, 72.27% water and 0.53% Rhodamine Red dye. The emulsion was emitted at a rate of 1.5 L of formulation/ha and estimated volume mean diameter was 36 and 33 μ m for the first and second spray, respectively (K.M.S. Sundaram, personal communication). Birds were collected with a .410 shotgun 2-48 h after spraying. Brains were stored in liquid nitrogen until assayed - a maximum of 12 days later. ChE assays were performed in our laboratory in Fredericton using the colorimetric technique of Ellman *et al.* (1961).

Analysis of data based on the entire sample for each species revealed no significant reduction in mean ChE levels. There was no significant difference (t-test) between ChE activity in birds exposed to a morning spray and in those exposed to an evening spray application, nor in birds collected within the first 24 h after spraying. Only four birds from spray plots exhibited ChE activity of more than 20% below the mean control value. They were a Tennessee warbler, a bay-breasted warbler and two American redstarts, in which ChE depression

was 26.6, 26.2, 35.2, and 37.5% respectively. No birds had ChE activity of less than one half the mean control value. This is in contrast to the results of a similar study (Busby et al., 1981) of the impact of the organophosphate insecticide fenitrothion on forest songbird brain ChE activity. The suggestion that 20% brain ChE inhibition indicates exposure and that 50% inhibition is sufficient for diagnosis of death has gained general acceptance. Under some circumstances, however, ChE inhibition can exceed 50% without mortality occurring. It is unlikely that any of the birds we collected were in danger of death through poisoning. There was no evidence of aberrant bird behavior that could be attributed to the spray. Only the four birds with more than 20% inhibition suggest exposure to the insecticide and potential minor sub-lethal effects.

We conclude that aerial spraying of two applications of Matacil^R 180F at 70 g a.i./ha over small plots had no significant inhibitory effect on brain ChE in songbirds exposed in the canopy and elsewhere in the forest. Further examination for potential hazard to birds of Matacil^R 180F in other formulations and in the context of larger spray plots would be prudent before translation to full-scale operational use.

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- Busby, D.G., P.A. Pearce, and N.R. Garrity. 1981. Brain cholinesterase response in songbirds exposed to experimental fenitrothion spraying in New Brunswick, Canada. Bull. Environ. Contam. Toxicol. 26: 401-406.
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INGESTION TOXICITY STUDIES:

1. EFFECTS OF ORAL DOSING WITH FENITROTHION ON THE GROWTH AND DEVELOPMENT OF NESTLING WHITE-THROATED SPARROWS

by

D.G. Busby

Canadian Wildlife Service
Environment Canada

Investigations in 1978 of the effects of fenitrothion on the behavior and reproductive success of white-throated sparrows revealed a reduced rate of growth and development and lower fledging weights of nestlings in areas sprayed against spruce budworm. Follow-up experiments in 1979 showed that 7 mg/kg doses of fenitrothion administered orally were capable of inducing a variety of effects ranging from slight growth impairment to death, depending primarily upon the age of the nestling. In 1980, the dosing experiments were expanded to determine the relative sensitivity of nestling white-throated sparrows of different ages to a range of doses. Also investigated were the effects of administering the same total doses in three equal portions over a period of three days so that exposure under actual spraying operations would be more closely approximated. The following conclusions can be drawn. Young nestlings are more sensitive than older ones and gradual exposure is less harmful to nestlings than single, complete doses. It is also apparent that surviving nestlings, following a day of weight loss, show a rate of weight gain exceeding that of control nestlings. However, the dosed nestlings generally fledge at weights significantly less than control birds. The implications of reduced fledging weight on survival of fledglings is unknown.

INGESTION TOXICITY STUDIES:

2. FENITROTHION IN NATURAL FOOD RESOURCES OF WHITE-THROATED SPARROWS

FOLLOWING SPRAY OPERATIONS

by

P.A. Pearce and D. G. Busby

Canadian Wildlife Service
Environment Canada

To set studies of fenitrothion dosing of white-throated sparrows in the context of potential ingestion exposure through feeding, residues were determined in a range of food resources used by that species. Fenitrothion analysis of arthropods and Polytrichum moss

capsules revealed a range of residues from 0.01 to 17 ppm up to two days following spray operations. Moss capsules contained the highest residue levels with a mean of 8.89 ppm in samples collected the same day that spraying took place. Spiders collected on spray day contained 1.13 ppm fenitrothion. Substrate-dwelling and free-flying insects contained 1.84 and 5.90 ppm fenitrothion, respectively, on the day following spraying. The residue data indicate that white-throated sparrow nestlings potentially suffer fenitrothion exposure of the same order of magnitude that produced abnormal growth rates in experimentally dosed birds, given that nestlings daily eat their own weight in contaminated food (see study of food habits of white-throated sparrows described elsewhere in this report). Future studies on the inhalation and dermal uptake of fenitrothion by nestlings will contribute to our knowledge of the total exposure of birds to sprays and of possible ramifications of that exposure.

INGESTION TOXICITY STUDIES:

3. FOOD HABITS OF NESTLING WHITE-THROATED SPARROWS

by
D.G. Busby

Canadian Wildlife Service
Environment Canada

In previous studies we have found that sub-lethal effects of fenitrothion spraying can disturb the reproductive activities of the white-throated sparrow, a potentially useful spray indicator species, causing desultory incubation, nest abandonment, singing irregularities and reduced nestling growth rates and fledging weights. Follow-up experimental dosing confirmed that small quantities (7 to 30 mg/kg) of fenitrothion could cause growth abnormalities in white-throated sparrow nestlings (manuscript in preparation). A study of fenitrothion in natural food resources of forest passerines revealed residues up to 17 mg/kg (manuscript in preparation). In the present study, we report the food items eaten by white-throated sparrow nestlings, to set in context the findings of the above studies so that dietary exposure to fenitrothion under normal operational spray conditions can be assessed.

This study was conducted at the Acadia Forest Experimental Station during the 1981 field season. Nests were located, observed daily to determine when eggs hatched, and 20 nestlings were collected after being fed by an adult. The alimentary tract was removed and stored in formalin until dissection to determine contents. The quantity of food brought per adult feeding trip was estimated by weighing

nestlings before and after the feeding. Lepidoptera larvae were the most frequently observed food eaten by nestlings, occurring in up to 50% of the samples. Of secondary importance were Diptera, Coleoptera and Hymenoptera. Nine orders of insects, Araneida (spiders) and Acari (mites) were observed in the samples. One-day-old nestlings were estimated to eat 176% of their body weight per day. Comparable figures for four-day- and seven-day-old nestlings were 72% and 77%, respectively. Our assumption that nestlings eat approximately their own weight daily thus appears to be valid.

SUMMARY OF INGESTION TOXICITY STUDIES
CONDUCTED ON WHITE-THROATED SPARROWS

IN NEW BRUNSWICK
by

P. A. Pearce

Canadian Wildlife Service
Environment Canada

A summary of the findings of our ingestion toxicity studies is as follows: (1) single experimental doses of as little as 7 mg/kg fenitrothion cause growth abnormalities in white-throated sparrow nestlings, (2) the food resource of nestlings contains up to 17 mg/kg fenitrothion after operational spraying, and (3) nestlings eat approximately their own weight in food daily. Therefore, if nestlings eat their own weight in contaminated food, the daily exposure would be sufficient to produce the growth reductions observed in the experimental dosing study. It is therefore concluded that the nestling growth reduction observed after operational fenitrothion spraying was a direct result of exposure to the pesticide. Although the implications of the slow growth rates and lower fledging weights are unknown, studies elsewhere indicate that fledging survival is reduced, especially at times of poor food supply or inclement weather conditions.

POLLINATORS

A REVIEW OF FOREST SPRAYING AND ITS EFFECT ON POLLINATORS

by
G. W. Wood

Agriculture Canada Research Station
Fredericton, New Brunswick
E3B 4Z7

Many species of plants are dependent upon, or benefit by, insect pollination, and by far the most important insect pollinators are domestic honeybees and native bees. The role of bees in the production of agricultural crops is more widely understood, but bees are also a key component in the reproduction of many wild plants and in the provision of food for birds and mammals in natural ecosystems.

Through the early years of forest spraying, there appears to have been little concern for these non-target insects, and initial research did not indicate any major impact. Buckner *et al.* (1975) studied the effect of fenitrothion and aminocarb on honeybees in Ontario and, although there was some mortality of foraging bees, they considered the impact on pollination and honey production to be negligible. Their few observations on wild pollinators led them to suggest that there would be nothing more than minor population disruptions. In a New Brunswick study, Varty and Carter (1974) noted some changes in the composition of wild bee species after an area had been treated with DDT or fenitrothion for 15 years but, on the basis of total pollinators, they concluded that there was no drastic change in wild bee activity following perennial spray operations.

However, in 1970 several blueberry growers, whose fields were located near fenitrothion-sprayed forests, reported unusually low pollinator activity and attributed their crop losses to the spray operation. It was not possible at that time to document the extent of bee mortality or the implication of forest spraying, but the evidence was sufficient to stimulate more research and create a greater concern for pollinators in future spray programs.

Subsequent studies confirmed that there is significant mortality of native bees in forests sprayed with fenitrothion. Plowright *et al.* (1978) recorded up to 100 percent mortality in caged bumblebees placed in sprayed forest, and Thorpe (1979) noted the absence of two common species of solitary bees in forest sprayed with fenitrothion. A correlation was also established between populations of native bees in blueberry fields and their proximity to sprayed forest (Kevan, 1975; Wood, 1977). In one field, where it was possible to measure bee activity before and after spraying of nearby woodland with fenitrothion, there was a reduction of over 90% in both solitary bee and bumblebee activity (Wood, 1977). Clearly, there is a risk to pollinators in the forest and also in adjoining agricultural land.

There has not been general agreement on the length of time required for bee populations to recover after spraying has terminated. Kevan (1977) suggested that it may require as long as ten years before wild bee activity returns to normal. Wood (1979), on the other hand, showed full recovery after three years, and Miliczky and Osgood (1979) reported similar findings in their study in Maine. Plowright and Rodd (1980) suggested substantial recovery of bumblebees is possible within the same year of exposure to spraying, providing there is favourable weather. Such recovery would be aided by immigration of bees from neighbouring unsprayed areas and greater colonization by species which emerge after the time of spraying.

In response to the evidence of bee mortality, some positive changes have been introduced into operational aspects of the spray program. An inventory of commercial blueberry fields and orchards was prepared and a no-spray zone established around identified sites. Initially, the no-spray zone was set at 3.2 km but, because significant insecticide residue was still being reported in some blueberry fields (Wood, 1974), further controls were introduced. Trichlorfon (Dylox^R) was used for a few years on woodland adjacent to commercial blueberry fields and orchards and when its use was discontinued in 1978, the no-spray zone was voluntarily increased to about 7 km by the applicator. Similar safeguards have not been possible for the many colonies of honeybees in the province, but apiarists are advised to keep their bees confined during periods of spraying in the area.

The previous measures have been effective in alleviating the concerns of the agricultural industry but cannot be applied for the protection of pollinators in the forest. The most promising approach towards resolving this problem would appear to be in a more selective use of insecticides. While fenitrothion and aminocarb are both rated as highly toxic to honeybees on the basis of laboratory tests (Atkins et al., 1976), the latter would be more acceptable from the standpoint of bee survival because it is currently applied at only one-third the dose of fenitrothion. Recent studies by Plowright and Rodd (1980) showed no detectable effect of aminocarb applied at 70 g a.i./ha on caged bumble-bees and, although some mortality of solitary bees was noted, the impact was considered to be quite small. Trichlorfon offers the least hazard to bees and would be most desirable, but its use will probably be limited to relatively small areas because of higher costs and restrictions on timing for effective control of budworm larvae.

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MONITORING FOR HARMFUL EFFECTS OF THE

1980 BUDWORM SPRAY PROGRAM ON

BLUEBERRY PRODUCTION IN NEW BRUNSWICK

by

G.W. Wood

Agriculture Canada Research Station

Insecticide drift was monitored in four commercial blueberry fields at the time of operational forest spraying (May 26 - June 3). Although these fields were selected because they were the closest to proposed spray blocks, none was within 3 km of sprayed forest.

A portable air sampler was mounted on a stand 1 m above ground near the centre of each field. The equipment, which had the capacity to sample approximately 3 L of air per minute, was in operation for a minimum of 2 h after the nearby forest was sprayed. The air was drawn through Amberlite XAD-2 resin, and insecticide residue (fenitrothion) was later extracted and analysed by gas-liquid chromatography.

Sampling was carried out after each of two spray applications and the concentration of fenitrothion did not exceed 0.05 ug/m^3 of air in any of the samples. In previous laboratory tests with fenitrothion aerosols, the LC50 for honeybees was estimated at 150 ug/m^3 . Although some allowance must be made for differences in size between bee species, the concentrations of fenitrothion aerosol found in blueberry fields during the time of forest spraying are considered to be well below toxic levels for domestic or native pollinators.

In addition to monitoring spray drift, assessments of pollinator activity and blueberry fruit set were made in two of the above fields and in two other fields located near sprayed forest. Bee activity and blueberry set in all fields was similar to that reported from these areas prior to the intervention of forest spraying, and did not suggest any harmful effect from the spray operation.

In 1981, the spray plan was such that effects on blueberry fields were considered unlikely, so further monitoring of drift in such areas was not carried out.

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FOREST ARTHROPODS

ENVIRONMENTAL IMPACT OF AERIAL SPRAYING ON PREDACEOUS ARTHROPODS IN FIR STANDS

by

I.W. Varty

Maritimes Forest Research Centre
Canadian Forestry Service
Environment Canada

Agricultural experience in use of insecticides for orchards and field crops is that repeated spray operations may destabilize natural control mechanisms. However, on the basis of a long-term study of the impact of fenitrothion spray regimes for forest protection, Varty (1977) concluded that the processes of predation and parasitism had not been damaged. To strengthen these earlier observations, predator sampling plots were established in 1977 for a four-year surveillance period to compare two perennial treatment regimes (fenitrothion sprayed annually and aminocarb sprayed annually) with an untreated control plot. The fenitrothion plot was sprayed in all four years, but the aminocarb plot was treated only in 1977-1979, and not in 1980 because aminocarb was not used that year.

Spiders

Spiders are the principal group of predaceous arthropods in the forest canopy. Long-term studies of spider abundance in balsam fir crowns (Varty 1977, 1980) have shown the perennial dynamics of the spider complex to be fairly stable and apparently little influenced by forest spray operations. Fenitrothion has little immediate effect on spiders, but aminocarb is highly toxic. The final year of study (1980) was aimed at adding more data on seasonal densities.

Spider densities were assessed based on samples of the population obtained from two branches per 100 trees per plot on each of three sampling days, one each in late May (pre-spray), late June (post-spray) and late July.

The branches collected were beaten over a canvas; live spiders were preserved in alcohol, then identified and tallied in the laboratory. Densities were expressed as number per m² of branch surface. From the successive collections, seasonal population density curves were prepared for comparison of perennial trends and seasonal patterns in the three regimes.

The data show that the spider communities were similar in all three plots; however, there were some differences in density dominance among species and in species diversity, probably due to the inevitable habitat variability in fir-spruce stands. The number of species varied between 12 and 32 per plot, but a few species (especially Grammonota angusta and Metaphidippus flavipedes) dominate the complex.

The general seasonal trend was a gentle increase in density from May to July, regardless of treatment. However, in 1980, the trend in the

fenitrothion plot was a mild decline while the untreated plots (aminocarb, control) maintained uniform seasonal densities.

The perennial trend in population densities over the four-year period, uniform in all three plots, was a rise from 1977 to 1979, followed by a decline in 1980. The data from the July population determinations given below illustrates the consistency of this trend.

Spider densities/m² fir branches

<u>Treatment Plots</u>	<u>Aminocarb</u>	<u>Fenitrothion</u>	<u>Control</u>
1977 (July)	3.1	6.3	5.0
1978	9.1	28.9	11.3
1979	18.6	35.9	21.0
1980	10.7	13.6	11.6

The untreated control plot with no history of insecticide usage before or after 1977 shows an annual doubling of population in 1978 and 1979, then a halving in 1980. The trends in the two treatment plots are parallel. The similarity in the aminocarb plot is surprising because aminocarb was observed to kill 37 - 69% of the spider populations in 1977-1979, but fenitrothion was seen to produce negligible mortality (<10%, when drop-trays (described below) were used as the means of detection).

Since it has been observed that some spider species are more prone to insecticide knockdown than others, it might be expected that a perennial application might slowly reduce the prevalence of susceptible and vulnerable species, and that such an effect, if severe, might be detectable as lowered species diversity in the complex. Thus the fenitrothion plot, with a spray history of 10 years of DDT and 12 years of fenitrothion since 1956, might be a good candidate for such a long-term effect. The species tally does indeed suggest that the fenitrothion plot is species-poor, as tabled below, but does not in itself prove that insecticide toxicity is responsible for the difference.

No. of spider species present on fir

<u>Treatment years</u>	<u>Branch samples</u>	<u>Aminocarb plot</u>	<u>Fenitrothion plot</u>	<u>Control plot</u>
1977	300	21	12	22
1978	300	19	17	27
1979	600	27	19	30
1980	600	32	21	28

Predaceous insects

Branch samples (two branches from 100 trees per plot, collected May-June-July 1980) contained about 20 species of bugs (mirids, nabids), lady

beetles, syrphid flies, lacewings, ants and others. Their abundance each year was low compared with spider densities. Predatory mites were also present at low densities ($<1/m^2$ branch area).

The perennial dynamics of the predaceous insect complex were parallel in all three plots. Densities were low in 1977 (ca. $1/m^2$), high in 1978 (ca. $3-7/m^2$), declining in 1979 (ca. $2-3/m^2$) and low again in 1980 ($1-2/m^2$). The parallelism regardless of treatment suggests that natural forces (such as the availability of aphid prey) may determine the perennial ebb and flow of abundance. However, it is evident that mean densities were consistently lower in the fenitrothion plot, intermediate in the aminocarb plot and highest in the untreated plot. This leaves open the hypothesis that insecticide regimes may have a depressant effect on population densities of predaceous insects in fir stands.

Drop-tray methodology

Drop-trays are $2m^2$ polyethylene trays used to collect spiders and insects which fall or spin down from foliage to the ground. Drop-tray samples are used to provide an index of insecticide penetration to the crown habitat and of toxicity to target budworm and non-target arthropods, when the usually heavy fall-out of fauna occurs in the first three days after spray.

In 1980, the natural rate of fall-out of arthropods from the balsam fir canopy was sampled in an unsprayed plot during the conventional spray period, late May to mid-June. A steady "rain" of many species in larval and adult stages was recorded; they were variously living, moribund and dead. Samples included bugs, beetles, sawfly larvae, lepidopterous larvae, dipterous larvae and adults, ants and parasitic wasp adults, and spiders. The aggregate tallies were large, equal to about one-quarter of the total population present on the trees at the end of period. Caution should be used in attributing arthropod fallout to insecticide effects in sprayed plots. Such tallies are a combination of natural fallout and toxic disturbance.

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KNOCKDOWN EFFECTS OF VARIOUS MATACIL^R FORMULATIONS
ON TERRESTRIAL ARTHROPODS, BATHURST, NEW BRUNSWICK, 1981

by

R. L. Millikin

Forest Pest Management Institute
Canadian Forestry Service
Environment Canada

A program was conducted to assess and compare the effects on the native arthropod fauna of balsam fir of different MATACIL^R formulations applied to small efficacy plots in New Brunswick in 1981 by FPMI's Field Efficacy Group. The formulations studied were: MATACIL 1.8D in Sunspray 6N^R, 1.8D in insecticide diluent (I.D.) 585 - a petroleum distillate, 1.8F in I.D. 585, 1.8F and Atlox^R in water, and Atlox in water.

Preliminary results indicate that MATACIL 1.8D in Sunspray 6N had a more pronounced and more diversified knockdown effect than the other formulations. When formulated with 585, MATACIL 1.8D had less of a knockdown than either of the new flowable (1.8F) formulations, and was comparable in effect to Atlox in water. This suggests that the Sunspray 6N was either the more toxic element of the formulation, or greatly increased the deposit of active ingredient over water or 585-based treatments. The new flowable formulations appeared to exert a slightly greater knockdown effect than the original 1.8D formulation. No prominent differences were noted between the water and oil-based sprays of the flowable MATACIL, although the water-based treatment appeared to be more effective on Lepidoptera. Some of the effects of the water-based spray may be attributable to Atlox, as a short-term knockdown effect was documented following the Atlox in water treatment. It should be noted that these conclusions may change after deposit assessment results become available.

Details of this program have been published in Forest Pest Management Institute File Report No. 15 "Preliminary report on the impact of MATACIL^R formulations on terrestrial invertebrates, Bathurst, New Brunswick, 1981" and will be included in a forthcoming FPMI Information Report.

FRESHWATER FAUNA

EFFECTS ON FRESHWATER ORGANISMS - A MANAGEMENT PERSPECTIVE

by
D. C. Eidt^a, and M. Redmond^b

^aMaritimes Forest Research Centre
Canadian Forestry Service
Environment Canada

^bFish and Wildlife Branch
New Brunswick Department of
Natural Resources

To provide commercial and sports fishermen with a continuing supply of freshwater and anadromous (that spawn in freshwater and go to sea) fish, it is necessary to manage the aquatic environment as well as regulate the harvest. There are many threats to the freshwater environment, which include dams, siltation, acidification, heavy metals, eutrophication, and pesticides.

All of these are results of human activities and are therefore under human control. All the activities are designed to improve the human lot and in every case there are trade-offs and compromise. Invariably compromises must be made when freshwater organisms are considered. Fisheries managers believe that we can generate hydroelectricity, build roads, mine minerals, manufacture goods, dispose of wastes, grow more food and fibre, and still have clear, cold streams and lakes that produce good harvests of fish. This can be optimized provided that existing legal requirements regarding environmental constraints are strictly obeyed.

Current spruce budworm control methods are not seen as a threat to aquatic resources. Forest insecticides are used extensively, over a large area of New Brunswick, but not intensively, (about 3/4 of a cupful per hectare or 2 1/2 acres) and usually not over the same areas in consecutive years. Insecticides may fall directly on water surfaces, may be washed in from terrestrial surfaces, or settle on water after drifting considerable distances in air. Countering input, insecticides may be screened out by the foliage canopy, evaporate in air or from the water surface, be diluted and dissipated, decompose, or become inactivated through bonding to sediments.

In 1980 and 1981, fenitrothion was the principal insecticide used, although a considerable area was sprayed with aminocarb in 1980. Fenitrothion was used in an emulsifiable concentrate formulation in which the insecticide was dissolved in Dcwanol^R, emulsified with Atlox^R and diluted with water, or in an oil formulation in which the insecticide was dissolved in Cyclosol 63^R and diluted with 585 oil. Aminocarb was used as a solution in 585 oil using nonylphenol as a surfactant.

Most field monitoring and experimenting in freshwater with fenitrothion has involved the emulsion. It has been shown that the effects on aquatic invertebrates are small, infrequent, and tolerable at aerial

emission rates of 210 g a.i./ha or less per application (Eidt, 1980). Effects on fish in natural systems have not been demonstrated. A very slight (<2%) reduction in size of young salmon in small streams after two sprays at 210 g a.i./ha has been hypothesized (Symons, 1977). It is possible, on the other hand, that when heavy drift of fenitrothion-distressed aquatic invertebrates occurs in streams, the extra food available to fish which engorge themselves may compensate for any subsequent temporary declines in food supply. All the evidence to date suggests that the oil formulation is neither more nor less hazardous to aquatic organisms than is the emulsion.

Operational aminocarb sprays are less toxic to aquatic organisms than are those of fenitrothion. Aminocarb is used at a third the amount per hectare and Ahern and Leclerc (1981) have shown in field experiments that the threshold for aminocarb-induced drift of aquatic invertebrates is higher (about 30 ppb) than the threshold using fenitrothion (about 20 ppb).

In spite of all reassurances, neither resource managers nor the scientists and technologists who support them, can become complacent. The introduction of new spray chemicals, new formulations, and new application technologies may pose new threats. We can never be certain that some subtle sublethal effect will not affect the aquatic resource and thus our vigilance must not diminish. The forest streams and lakes of New Brunswick harbour healthy, diverse invertebrate communities. Fish, if not as abundant or as large as we might remember them, would have become so for reasons of accessibility, increased fishing pressure, and habitat changes wrought by man, probably not the use of present-day forest insecticides.

With all the assaults on the resource, it is extremely difficult for the resource manager to assure a continuing supply of fish. It is just as important as stocking and regulation of fishing, that we continue to monitor the impacts of forest insecticides and other threats to the resource. We must also continue to seek more effective and safer insecticides and ways to apply them, and search for safer, more effective alternatives for controlling spruce budworm.

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PARTITIONING OF FENITROTHION AND INSECT DRIFT IN STREAMWATER

by
D.C. Eidt^a, and V.N. Mallet^b

^aMaritimes Forest Research Centre
Canadian Forestry Service
Environment Canada

^bDépartement de Chimie
Université de Moncton

Fenitrothion was sprayed with a mist blower on the surfaces of two small (ca. 180 L/sec) streams in New Brunswick in 1981. An approximately 50 m stretch of each brook was sprayed: one with emulsifiable concentrate (EC) and the other with an oil solution containing the adjuvants used operationally in New Brunswick in 1981. To determine the distribution of benthos drift in the water column, a benthos drift barrier net was placed about 50 m downstream of the sprayed section, and drift was sampled at increasing distances downstream. At intervals downstream, water and sediment samples were collected for fenitrothion analysis.

Water for analysis was collected at midstream from three levels of the water column: the top 1 cm including the surface; halfway to the bottom, and as near the bottom as possible without collecting sediment. In the first sample taken, during the EC-treatment 70 m downstream of the treated stretch, the concentration was apparently lowest near the bottom. But one hour after treatment and later, and 180 m and farther downstream, mixing was essentially complete. Most concentrations were in the range 1 to 4 ppb. The usual downstream diminution of concentration occurred.

In the stream treated with the oil solution, fenitrothion was found at all levels in the water column, 33 min after spraying began and later, and 70 m downstream and farther. It was expected that the fenitrothion would stay on the surface in the oil slick, but concentrations at various levels indicated complete mixing. Most concentrations were in the range 5 to 15 ppb.

In both streams, samples were taken in back eddies or still areas along the banks to see if fenitrothion accumulated in such places. Concentrations were of the same order as those found in midstream samples.

Small amounts of aminofenitrothion were detected in some water samples from both streams from all levels, particularly at times when fenitrothion had been present for an hour or more. Fenitrooxon was also found in small amounts, but less often.

When water samples from both streams were filtered through 0.45µ microfilters, about half the fenitrothion was found on the filters. This implies that most of the fenitrothion was sorbed on suspended particulates; in a laboratory test we found that the cellulose acetate filter retained only 5% of fenitrothion from double-distilled water containing 20 µg fenitrothion/L.

Sediment samples from the top centimetre of the stream bottom were analysed for both fenitrothion and organic content. Using the samples from the stream treated with oil formulation, a positive, nearly linear relationship was found between percent organic content and the logarithm of the fenitrothion concentration. Fenitrothion clearly partitioned to the organic fraction, but in the analysis no distinction was made among plant or animal, living or dead components.

Although all component taxa were found at the top, middle, and bottom of the water column, the vertical distribution of invertebrate drift was found to vary depending on the location. After treatment, chironomid larvae, for example, were found to be more abundant near the top at one sample station and near the bottom at another. It is concluded that the hydrodynamics of stream flow affected the vertical distribution more than the insecticide did. It is important therefore that drift nets extend from the bottom to and including the surface, to get samples that are representative.

A detailed report is in preparation.

THE MOVEMENT OF FORMULATED AMINOCARB
THROUGH THE SURFACE MICROLAYER IN LENTIC SYSTEMS
AND EFFECTS OF EXPERIMENTAL AMINOCARB
SPRAYING ON AQUATIC MICROBIOTA

by
J.K. Elner^a and D.J. Wildish

Fisheries and Environmental Sciences
Fisheries and Oceans Canada

(^aPresent affiliation: Fundy Isles Marine Enterprises Ltd.)

From July 1979 to July 1981 we collaborated on a series of aquatic microbial studies funded by CANUSA (The Canada/United States Spruce Budworms Program). All of this work involved experimental spraying with the nonylphenol formulation of aminocarb.

A Solo back-pack sprayer was used to treat three of the four study ponds at 140 g a.i./ha (pond 1); 280 g a.i./ha (pond 2); and 700 g a.i./ha (pond 3). (The fourth pond was used as a control.) As expected, and as probably also occurs with operational spraying, it was found impossible to achieve uniform theoretical aminocarb concentrations, consequently controlled experiments were conducted to determine some of the causative factors.

From the results of field analysis and controlled experiments, it appears that aminocarb moves through the water column achieving maxima at the surface instantaneously, at 0.2 within 22-64 h, and at 0.4 m after approximately 72 h. In the controlled experiments, residence times of aminocarb at the surface were brief, declining to undetectable levels in 29 h. The transfer of aminocarb from upper to lower strata and the eventual diminution of concentration were found to be dependent upon physical mechanisms such as wind.

In the field experiment, even at the maximum spray rate of 700 g a.i. aminocarb/ha (equivalent to concentrations of up to 53 ppb in the pond), no discernible impact on microbial activity was evident. Carbon-14 assimilation experiments showed that aminocarb concentrations of 0.98 ppm were needed to cause a 50% reduction of carbon assimilation in natural pond algal communities. Concentrations of 1.5 ppm aminocarb were sufficient to cause total cessation of carbon uptake, yet, after exposure to 2.24 ppm, recovery of algal carbon-14 assimilation took place in 72 h, probably as a result of the existence of insecticide-resistant algal cells.

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TOXICOLOGY

TOXICOLOGY: SOME BASIC FACTS

by

I. W. Varty

Maritimes Forest Research Centre
Canadian Forestry Service
Environment Canada

The two chemical insecticides used operationally in New Brunswick in 1980 and 1981 were fenitrothion and aminocarb (formulated from Matacil 1.8D). The two compounds belong to quite different families of pesticides. Fenitrothion is an organophosphate, one of scores of such compounds synthesized since 1945, including malathion and phosphamidon. Aminocarb is a carbamate, a chemical family which began development with the insecticide carbaryl (Sevin) in 1953. Both organophosphates and carbamates act by inhibiting the nerve enzyme cholinesterase. In insects, as in mammals and birds, the insecticide prevents cholinesterase from regulating the neurotransmitter acetylcholine in the signalling of messages across the interfaces (synapses) of nerve fibres. Although their effect is much the same, the

chemical actions of organophosphates and carbamates are quite different. Organophosphates inhibit cholinesterase by phosphorylating (combining with) the active site of the enzyme; whereas carbamates form a more tenuous chemical bond with the enzyme, such that cholinesterase depression is rapidly reversible.

Toxic effects on nerve enzymes may be caused not only by the parent compound, but also by the breakdown products, either those produced by photochemical and hydrolytic processes in the environment at large, or those produced by metabolism within the poisoned animal itself.

The metabolic products of fenitrothion are well-known (Sumitomo Chemical Co., 1978). Much of the effectiveness of fenitrothion is caused by its oxidation to fenitrooxon in the animal body, where the oxon is an inhibitor of cholinesterase and other esterases (especially in the plasma and liver of mammals). No-effect doses, as determined by measurement of plasma cholinesterase inhibition, have been established in laboratory animals. The rate of metabolism and the production and elimination of the metabolites have also been documented in certain animals. Further investigations of the effects and persistence of fenitrothion when exposure is chronic and subacute have been conducted.

The toxicity of any insecticide is usually characterized by the measurement of its LD50 in a test animal (see definition, p. 35). According to Sumitomo Chemical Co. (1978) "The acute toxicity of fenitrothion varies according to species of test animal, sex, route, method of administration and/or the formulation tested. The acute LD50 in mammals ranges from 33 ppm (rat, male, intravenous) to 1850 (guinea pig, male, oral)." The toxicities of metabolites may be greater or lesser than those of fenitrothion itself.

The LD50 of aminocarb over a range of test animals is roughly equivalent to fenitrothion values. Its metabolism has also been studied (although not so extensively as for fenitrothion). Several metabolic studies have identified hydrolysis as the main process at the ester sites in animal tissues, and have determined the main breakdown products. Experiments with rats have shown that the breakdown and elimination of injected aminocarb is rapid. But again, knowledge is far from complete.

Moreover, as is often pointed out by critics of pesticide usage, laboratory toxicological tests usually examine active ingredients, not the formulated product which is actually sprayed. The formulation is important to the actual toxicity. There remains some dispute among scientists as to the importance of formulation adjuvants, such as nonylphenol, in field conditions.

One major problem in toxicology is acquisition of knowledge of the pathway of entry of insecticides into each organism. The main routes for terrestrial organisms are:

(1) skin contact, particularly through the feet where skin is not protected by fur, feathers, or scales.

(2) ingestion of poisoned prey or contaminated plants.

(3) inhalation of aerosols and vapors. The droplets inhaled are the numerous minute droplets characteristic of drift; the larger droplets (greater than 25 μ m) may be too large to enter the lung alveoli and in any case settle out of the drift too quickly to be available for a long period of intake. While inhalation is a particular risk to vertebrate animals, it seems probable that invertebrates may absorb vapors emanating from residues on foliage, through their tracheae (insects) or book lungs (spiders) or the exoskeleton itself. There are analogous avenues in aquatic organisms (pathways through the skin, the digestive tract and the blood or air gills). The water surface is presumably the most contaminated part of an aquatic system just after spraying, so that organisms active at the surface are particularly vulnerable.

Laboratory toxicology is only a guide to possible hazards. Insecticides can poison many kinds of organisms, and it is important to explore pathways and pathologies through the test tube, but laboratory methods have their limitations. It can be difficult to extrapolate, from chronic laboratory toxicity tests where animals are continuously exposed to uniform dosage levels, to field situations where concentrations of the insecticides may rapidly decline. Tests using cell cultures can be particularly misleading, because such systems exclude the variously effective metabolic defences against exotic toxins. Ultimately the real hazard, if there is one, is in the field. The question is not "Is it poisonous?", but "What is the lowest dose having unacceptable poisonous effects?" Thus field surveillance must continue, notwithstanding the low risks or the high risks indicated by the laboratory toxicologist.

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LABORATORY TOXICITY STUDIES OF MATACIL^R AND
FENITROTHION SPRAY FORMULATIONS AND THEIR
COMPONENTS IN 1980

by

W.R. Ernst, G.R. Julien, K.G. Doe, W.R. Parker, and W.G. Pelly

Environmental Protection Service
Environment Canada

Effects on two aquatic animal species of some of the spray formulations and their components used in the 1980 budworm spray program were investigated in laboratory toxicity tests. The toxicity of nonylphenol (an adjuvant to the Matacil 1.8D^R formulation) was evaluated in lethal bioassays using rainbow trout (Salmo gairdneri) juveniles and embryos, and Daphnia pulex. The most sensitive organism to nonylphenol was D. pulex followed by rainbow trout juveniles. While the LC50 values determined in these experiments were all greater than nonylphenol residue concentrations which are normally observed after forest sprays, they were within the range of localized environmental concentrations which have been documented after seasonal maximal sprays. (A seasonal maximal spray is a single application of a spray at the maximum dosage allowable under the terms of the registration for that product with Agriculture Canada.)

Bioassays were also conducted on rainbow trout and Daphnia in order to determine the toxicity of fenitrothion and Cyclosol 63^R (a registered insecticide solvent oil), alone and in combination. Results indicated that the fenitrothion/Cyclosol 63 formulation is more toxic to rainbow trout than a strictly additive treatment of the relative toxicity of its components would suggest. Concentrations of formulation as low as 32 ppb rapidly immobilized and ultimately proved lethal to Daphnia. The synergistic effect of fenitrothion and Cyclosol 63 in formulation may mean that safety margins to aquatic species in programs utilizing this formulation may not be as great as previously predicted. These data indicate that the formulation may be almost three times more toxic to rainbow trout than would be expected if toxicity contributions of formulation components were strictly additive.

This study and other aspects of environmental monitoring of the 1980 New Brunswick spruce budworm spray program by the Environmental Protection Service, Atlantic Region (Environment Canada) as described in the EPS Surveillance Report EPS-5-AR-81-3.

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ACUTE TOXICITY AND BIOACCUMULATION POTENTIAL OF MATACIL 1.8F^R
FORMULATIONS AND THEIR COMPONENTS TO AQUATIC FAUNA

by

K.G. Doe, W.R. Ernst, W.R. Parker and W.H. Horne

Environmental Protection Service
Environment Canada

Bioassay experiments were conducted to test the toxicity of Matacil 1.8F^R and its proposed operational formulations and individual components to several aquatic species. Additionally, because Matacil 1.8F contains a finely-milled particulate, aminocarb, which has the potential to be accumulated by filter-feeding aquatic organisms, an experiment was conducted using mussels (Mytilus edulis) to test such a possibility.

Rainbow trout (Salmo gairdneri) bioassays indicated that of all the 1.8F formulation components tested (Sunspray 7N^R, 585 diluent, Atlox^R and technical aminocarb), the technical aminocarb was the most toxic. In the case of the proposed operational water formulation (25.7% 1.8F concentrate, 4.8% Atlox 3409F and 69.5% water) the toxicity was due entirely to the aminocarb content. In the proposed operational oil formulation (26.7% 1.8F concentrate, 73.3% 585 diluent oil), however, only 63% of the acute lethal toxicity could be attributed to aminocarb and the remaining 37% was attributed to the diluent oil. The Matacil 1.8F concentrate was also about one tenth as toxic to rainbow trout as Matacil 1.8 concentrate which contained identical quantities of aminocarb plus the solvent nonylphenol (McLeese et al., 1980b).

The acute toxicity of the oil and water formulations was also investigated using a variety of aquatic invertebrates, which included the water flea (Daphnia pulex), a freshwater bivalve (Anodonta sp.) and a saltwater mussel (M. edulis). The most sensitive species tested was D. pulex which was immobilized after a 48 h exposure to 0.38 mg/L of the operational oil formulation. Both M. edulis and Anodonta sp. tolerated exposure to at least 260 mg/L of both formulations for 96 h without observable effects.

During 30-day uptake and elimination experiments with the water formulation at sublethal concentrations (0.05 to 0.5 mg/L), bioconcentration factors (concentration in tissue/concentration in water) for M. edulis ranged from 1.48 to 2.58 for various exposure times. Concentration factors stabilized after several days to approximately 1.5. When mussels which had been exposed to the water formulation were placed in clean water, the aminocarb concentration in tissues dropped to non-detectable levels in less than 1 day. The accumulation potential for Matacil 1.8F is, therefore, very similar to that previously reported (McLeese et al., 1980a) for Matacil 1.8D.

Due to its lower acute toxicity and similar bioaccumulation potential for those aquatic species tested we suggest that Matacil 1.8F would be preferable to Matacil 1.8D as an operational forestry insecticide.

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LETHALITY AND ACCUMULATION OF ALKYLPHENOLS

IN AQUATIC FAUNA

by

D.W. McLeese, V. Zitko, D.B. Sergeant, L. Burridge, and C.D. Metcalfe
Fisheries and Environmental Sciences
Fisheries and Oceans Canada

The use of nonylphenol in a pesticide formulation and the generally widespread usage of other alkylphenols in various products prompted this study.

Lethal thresholds of alkylphenols, ranging from butyl- to dodecylphenol, to shrimp (Crangon septemspinosa) and to juvenile Atlantic Salmon (Salmo salar) are 0.15-2.7 and 0.15-1.0 ppb, respectively. The lethality and bioconcentration of alkylphenols are sufficiently high to warrant a more detailed study of their sources, environmental fate and effects.

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EFFECTS OF MATACIL^R ON CULTIVATED CELLS
by

M.F. Li, R. Zwicker, and V. Marryatt

Fisheries and Environmental Sciences
Fisheries and Oceans Canada

Cultured populations of 'L' cells - a standard cell culture used in cytology - were reduced dramatically within the first 24 h of exposure to an emulsion concentrate formulation of Matacil at 5 ppm. The cytological effects of Matacil were studied by light and electron microscopy. At least part of Matacil's observed acute toxic effects were due to cellular destruction. The toxicity of the constituents of Matacil (approximately 20% aminocarb, 50% nonylphenol, and 30% diluent oil) was evaluated and the major toxicity observed was due to the presence of nonylphenol.

SUBACUTE TOXICITY OF TECHNICAL FENITROTHION

IN MALE RATS

by
B. Trottier^a, A.R. Fraser^a, G. Planet^b, D.J. Ecobichon^c and G. Rona^d

^a Département de Chimie, Université de Moncton

^b l'Hôpital Georges Dumont

^c Department of Pharmacology and Therapeutics,
McGill University

^d Lakeshore Diagnostic Services Inc.,

Commercially-raised (CD-strain) male rats weighing 100-125 g received fenitrothion by oral gavage (2.5, 5.0, 10.0 or 20.0 mg/kg/day) for 30 consecutive days. Control animals received equivalent volumes of taurocholate vehicle. Animals were killed for examination at 8, 15, 22 and 30 days during treatment and at 8, 15, 29, 57 and 85 days after terminating treatment. The brain plasma and erythrocyte cholinesterases, hepatic and renal non-specific carboxylesterases were assayed. Serum biochemical markers of hepatic function were measured. Histologically strained sections of liver were examined by light microscopy.

Fenitrothion, at doses between 2.5 and 10 mg/kg body wt, caused few observable deleterious effects to male rats except those effects on tissue esterases associated with organophosphorus esters. Only 8 of 36 animals receiving the 20.0 mg/kg dose died, all in the first week of treatment. A dose-dependent decrease in tissue esterase activity was observed which persisted throughout the entire treatment period. Periodic signs of overt toxicity were observed only in animals receiving 20 mg/kg/day. Tissue esterase activities returned to control levels within 1 or 2 weeks of stopping treatment. No significant treatment-related changes were observed by serum biochemistry or by light microscopy.

This study was supported by the Department of Health of New Brunswick to which the following report was submitted December 1979: "Fenitrothion Subacute Toxicity Following Administration as an Emulsion in Sodium Taurocholate: Observed Biochemical and Morphological Parameters in Male Rats".

EVALUATION OF HAZARDS OF PESTICIDES USED IN FOREST SPRAYING

TO THE AQUATIC ENVIRONMENT

by

V. Zitko, and D.W. McLeese

Fisheries and Environment Sciences
Fisheries and Oceans Canada

A "hazard assessment mode" using physicochemical constants has been developed which will be broadly applicable in the field of environmental toxicology. This model is not intended to define precisely nor presage the effect of any individual chemical on a species or community per se, but instead it is intended to serve as a method by which chemicals designed for a specific use can be contrasted with one another as a factor in deciding which substances generally constitute less of an environmental risk. It is hoped that this model will be of particular use in the assessment of chemicals currently in use or under consideration for use in broad-scale forest spraying applications.

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- Zitko, V., and D.W. McLeese. 1980. Evaluation of hazards of pesticides used in forest spraying to the aquatic environment. Can. Tech. Rep. Fish Aquat. Sci. No. 985.

INSECTICIDE ANALYSIS

STATE OF THE ART IN THE RESIDUE ANALYSIS

OF FENITROTHION AND AMINOCARB

by

G. L. Brun

Water Quality Branch
Inland Waters Directorate
Environment Canada

Introduction

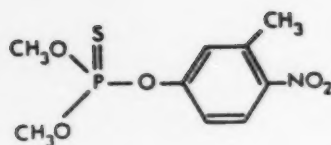
Fenitrothion (0,0-dimethyl 0-(3-methyl-4-nitrophenol) phosphorothioate) is an organophosphorus insecticide which was first introduced during 1959 in Japan by Sumitomo Chemical Company. The insecticide is known under such trade names as Folithion^R and Sumithion^R. Aminocarb (4-dimethylamino-3-methyl-phenol methyl- carbamate) is a carbamate insecticide which was introduced in the early sixties by Bayer Luverkusen as Matacil^R.

These two insecticides in recent years have been used extensively in many countries around the world. Justifiably, concerns have arisen as to the relative safety of these toxic synthetic materials to people and the environment. In light of this, the residue chemist is faced with the challenge of being able to identify and measure minute amounts of these substances in a wide range of samples such as water, food, air, soil, plants and animals.

This paper is an attempt to elucidate the procedures and techniques presently involved in the residue analysis of fenitrothion and aminocarb. Because the current methodology has not changed substantially in the time since the last report was prepared, this section repeats in its entirety the description of the "state of the art" given in the 1978-79 EMOFICO report.

Chemical and Physical Properties

Fenitrothion is a yellowish-brown liquid which is soluble in most organic solvents, of low solubility in aliphatic hydrocarbons and practically insoluble in water (20 mg/l). Its vapor pressure is 6×10^{-6} mm Hg at 20°C and specific gravity is 1.3. Pure aminocarb is a white crystalline solid with melting point 93-94°C, is readily soluble in polar organic solvents, moderately soluble in aromatic solvents and slightly soluble in water (2000 mg/L). Its vapor pressure is less than 7.5×10^{-5} mm Hg at 20°C. The chemical structures are shown below.



Fenitrothion (MW 277)

RESIDUE ANALYSIS OF FENITROTHION

Fenitrothion chemistry is well documented and its analysis, like that of most organophosphates, is straightforward. In the last four or five years, the state-of-the-art has not changed much except in the area of pesticide degradation. Nevertheless brief discussions will follow on the conventional methods presently practised.

Extraction

The analysis of water is usually done by serial solvent extraction with either chloroform (Ripley *et al.*, 1974) or another appropriate solvent. The new widely acclaimed use of XAD macroreticular resins has been extended to fenitrothion analysis by Berkane *et al.* (1977). The same procedure was modified by Pearce *et al.* (1979) to collect rain water over extended periods of time. An important advantage is the stability with time of the insecticide on the resin.

Soil/sediment samples are extracted with either ethyl acetate (Grift and Lockhart, 1974) acetonitrile or solvent mixtures such as hexane:acetone (50:50). On the other hand, fish tissue and vegetation are extracted with ethyl acetate (Grift and Lockhart, 1974) or acetonitrile (Hallett *et al.*, 1975). Yule *et al.* (1971) analysed air samples with a solid adsorbent/solvent trap.

Clean-up

Clean-up of most extracts is seldom required when gas liquid chromatography (GLC) coupled with flame photometric detection (FPD) is used. Nevertheless highly-colored extracts may indicate the presence of a wide variety of coextractives such as: sulfur, humic substances, natural oils, lipids, waxes, plant pigments, etc... which could cause interferences. An acetonitrile:hexane partitioning followed by a Florisil or silica-gel column clean-up is effective for most sample types. Sulfur can be removed by precipitation with elemental mercury. Foliage extracts usually require further clean-up especially if detectors other than the FPD are used. Charcoal-celite used by Moody *et al.* (1978) has been found effective in some laboratories to remove most of the color in foliage but this procedure requires close scrutiny because of fluctuating recoveries observed.

Recoveries using these procedures on the average are complete. Losses may occur especially during clean-up procedures if controls are not run in parallel samples and closely monitored to assure maximum recovery. Degradation products such as amino-fenitrothion, fenitrooxon and S-methylfenitrothion were also successfully recovered along with the parent compound (Moody et al., 1978; Mallet et al., 1978).

Residue methods to analyze other degradation products of fenitrothion such as reported by Miyamoto (1977) and Greenhalgh (1979) are being researched in some laboratories. The unavailability of chemical standards renders this work much more difficult because the compounds have to be synthesized and purified beforehand, a task that would be alleviated and less costly if the pesticide producers would do their share.

Identification and Quantities

The instrumentation used routinely continues to be GLC with any one of the many phosphorus-specific detectors now commercially available. The flame photometric detectors have been extensively used and appear to be more rugged, less susceptible to artifact interferences, and a bit less sensitive than the alkali flame ionisation detectors (AFID) which are specific to both nitrogen and phosphorus organic compounds. Typical minimum detectable amounts are illustrated in the following Table:

Minimum Detectable Amounts of Fenitrothion and Aminocarb in Various Types of Samples

Sample	Fenitrothion		Aminocarb		
	FPD	AFID	HECD ^A	AFID	HPLC ^B
Water	0.01 μ g/L	0.01 μ g/L	0.1-0.5 μ g/L	0.01 μ g/L	0.05 μ g/L
Tissue	0.05 mg/Kg	0.01 mg/Kg	0.1-0.5 mg/Kg	0.01 mg/Kg	0.05 mg/Kg
Soil/Sediment	0.01 "	0.01 "	0.1-0.5 "	0.01 "	0.05 "
Foliage	0.01 "	0.01 "	0.2 "	0.01 "	0.05 "

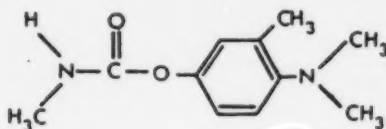
^AHECD = Hall Electrolytic Conductivity Detector

^BHPLC = High Performance Liquid Chromatography with fluorescence detector.

Confirmation

Reliable results are possible by using a simple chemical confirmation procedure. An easy one involves the chromous chloride reduction (Forbes et al., 1975) of fenitrothion to aminofenitrothion; and another (Coburn and Chau, 1974), which is more tedious, involves the reaction of the phenolic hydrolysis product with pentafluorobenzyl bromide to yield a halogenated derivative. Aminofenitrothion is then quickly determined by GLC with a phosphorous-specific detector, whereas the latter product is analysed again by GLC but instead with an electron capture detector. The presence of either of these products in the derivitized extract constitutes a positive confirmation.

Although the aforementioned confirmatory procedures are quite reliable and relatively much less expensive, the ultimate confirmation lies with gas chromatography-mass spectrometry (GC-MS). Pre-requisites for this type of analysis are that sample extracts be relatively clean and levels be sufficiently high to permit detection.



Aminocarb (MW 208)

RESIDUE ANALYSIS OF AMINOCARB

Unlike organophosphates the analysis of carbamates is much more difficult, requiring a high degree of skill to produce reliable data. A substantial problem which contributes to this difficulty is their thermal instability on GLC columns. Alternative special procedures and techniques must be used such as derivitization, which in this case is defined as a technique to transform labile compounds to more stable ones, amenable to GLC; or "milder" chromatographic processes such as high performance liquid chromatography.

Extraction

The extraction of aminocarb, similar to other N-methyl-carbamates, is pH-dependent. For example, the substrate of an aqueous solution of aminocarb will not partition into an organic solvent phase at pH < 3 but will partition quantitatively at neutral pH.

The property is typical of amines which are able to act as weak bases by accepting protons from acids to form soluble salts. Aminocarb contains a tertiary amine moiety which tentatively explains why it does not extract into the organic phase at acid pH, such as is the case with other N-methyl-carbamates that do not have an amino group. This obviously is a very important property that can be used effectively to clean up sample extracts of undesirable materials.

Polar solvents such as ethyl acetate and methylene chloride, according to Brun and MacDonald (1978), are conveniently used to extract aqueous samples, and so are XAD resins which are again very well suited for rain water collection. Sediment/soil samples should be treated with weak acid ammonium acetate as per the method of Caro *et al.* (1973) to hydrolyse any conjugation or binding of aminocarb that may occur on the polar reactive sites of soil molecules.

Clean-up

When further clean up is required after acid-base partitioning, Florisil column fractionation described by Lawrence et al. (1977) may prove helpful.

Identification and Quantitation

As pointed out earlier, the major problem in carbamate analysis is with thermal degradation on GLC columns. However it has been found that with certain carbamates, such as aminocarb, degradation is negligible on OV-17 columns if proper instrument parameters are chosen (Kuhr and Dorough, 1976). Analysis by this technique has been proven successful in many laboratories when used with a nitrogen-specific detector. Minimum detectable amounts of 0.5 µg/L and 0.5 mg/Kg for water and solid substrates respectively (Brun and MacDonald, 1978) were determined with the HECD. Laboratories using AFID's and modified versions of the HECD report somewhat better sensitivities (previous Table).

Derivatization prior to GLC with reagents such as hepta-fluorobutyric anhydride (HFBA) (Sundaram et al., 1976) is considered not practical if large numbers of samples are to be analyzed. The direct analysis of aminocarb appears to be a better approach. Reflecting the author's bias, HPLC is appealing and promising in this regard because the separation mechanism is carried out at ambient temperature which practically rules out decomposition during the process.

The UV-absorbance and fluorescence detectors are two very sensitive detectors commercially available today with HPLC. Aminocarb which exhibits natural fluorescence is detectable (Brun and MacDonald, 1978) down to levels of 0.05 µg/L in water, which is approximately ten times better than the UV detector (254 nm) and GLC method using the HECD. Confirmation of aminocarb is possible by GC/MS.

Gaps exist in chemical methods to confirm results, and in methods to determine and analyze degradation products in various types of samples. Sensitivity of methods could stand improvement to bring detection levels one order of magnitude lower.

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A STUDY OF THE DEGRADATION AND KINETICS OF AMINOCARB IN WATER

- A MULTI-RESIDUE ANALYTICAL METHOD FOR THE

PARENT COMPOUND AND SOME OF ITS DEGRADATION PRODUCTS

by

D. Levesque, and V.N. Mallet

Département de Chimie
Université de Moncton

This study of the insecticide 4-dimethylamino-3-methylphenyl N-methyl carbamate (commonly known as aminocarb) dealt with: (i) the methodology for the quantitative analysis of aminocarb and some derivatives in water; (ii) the stability of aminocarb in water; and (iii) the identification of some of the degradation products of aminocarb in water.

Essentially, aminocarb and several derivatives may be recovered quantitatively from water using the resin Amberlite XAD-4, although XAD-2 and XAD-7 may be used. The derivatives that could be recovered quantitatively at pH 7.0 were the hydrolysis product, i.e., Matacil phenol, and two other derivatives containing a formyl group. The study was not exhaustive, however, and did not include all possible derivatives.

Some kinetic information was obtained on the disappearance of aminocarb in water. This was done by measuring the per cent recovery of aminocarb with time, plotting the results and calculating the half-life. Thus "half-life" values were obtained for aminocarb in water under various environmental conditions by varying the pH, the temperature, adding metallic ions, oxygen, by keeping the solution in darkness or exposing it to sunlight, etc. The half-life of the control was 342 ± 10.2 h and the fastest degradation was

observed at high pH. (The control consisted of 100 mg of aminocarb in one L of double-distilled water with pH adjusted to 7.0. This control solution was kept in darkness at 25°C). Many data were collected for statistical purposes.

Finally, an attempt was made to identify some of the degradation products of aminocarb in water. This experimentation was carried out only in distilled water at pH 7.0 in darkness. Even so, many degradation products were evident after a short time. Of the many derivatives detected, valid gas chromatography/mass spectrometry data were obtained for only 10 chemicals, including the parent compound. The identity of three of the chemicals was confirmed by comparison with chemical standards. Included among the suggested chemical structures were two compounds which have never been reported before as derivatives of aminocarb.

INSECTICIDE DISTRIBUTION AND PERSISTENCE

ADVANCES IN DOCUMENTATION OF INSECTICIDE DRIFT FROM

FOREST PROTECTION OPERATIONS IN NEW BRUNSWICK

by

I.W. Varty

Maritimes Forest Research Centre
Canadian Forestry Service
Environment Canada

The forest spray program in New Brunswick is designed to deliver insecticide droplets in reasonably homogeneous coverage of the foliage of target stands across each designated spray block. To this end Forest Protection Ltd. ordinarily uses a team of three TBM spray aircraft under the guidance of two Cessna flag planes so that spray runs are correctly orientated, spaced and controlled for parallel swaths and precise cut-off.

Downwind drift of the spray cloud is an indispensable mechanism for homogeneous distribution of droplet deposits across blocks in budworm-infested forests. Inevitably some of the spray formulation emitted over spruce and fir forests drifts into non-target areas where contamination, however slight, is unwelcome. Public apprehension is centred on (a) fear of poisoning near and distant bystanders, either directly or by hypothetical enhancement of viral disease virulence, and (b) fear of destabilizing natural communities and agricultural crop systems. Drift has been variously blamed for the incidence of Reye's Syndrome in people, for crop losses of blueberries and honey, for interference in food chains culminating in salmon and trout, and for contaminating shellfish and water supplies.

One problem in coping with these allegations was the lack of information on insecticide transport beyond the target block. Therefore, in 1978 the New Brunswick Department of Natural Resources in consultation with the Department of Health, set up a Drift Task Force to review the state of the art. Within the Task Force, an interdisciplinary group is modelling and testing the off-swath movement and deposition of aerosols and vapors in the interest of improving operational efficacy and hazard evaluation. However the effort in promotion, funding and logistic support of field experimentation in drift is largely credited to Forest Protection Ltd.

The problem of drift is not easily defined. It is not merely a matter of quantifying the average concentration of drift at a range of distances downwind. Because of variations in the formulation and aircraft delivery, and terrain and weather conditions, every scenario will produce a different set of data. It is also necessary to describe the quality of drift (aerosol or vapor phase, chemical change, droplet diameter spectrum), so that health

authorities and biologists can calculate exposure in their hazard assessments. To minimize expensive field measurements it has therefore been necessary to direct the physical research towards computerized mathematical models which are designed to take into account changes in the input factors.

A sequential development of models is being directed to the spray process in terms of four events:

1. droplet spectrum generation by aerodynamic shearing stresses on the emerging liquid sheet at the spray nozzle;
2. transport of the aerosol by gravity, wind, and the trailing vortices of the aircraft (or wake);
3. deposition as influenced by formulation, droplet size, turbulence, and receptor characteristics; subsequent vapor flux from deposits; and
4. biological effect.

These aspects of drift were explored in a symposium on "Long-distance Drift of Insecticides from Aerial Sprays in Forest Operations", using a tract of New Brunswick forest as a test scenario. Drs. J.J.C. Picot and D.D. Kristmanson (1980a,b) of the Chemical Engineering Department of the University of New Brunswick subsequently developed models of spray emission and near-field transport of the aerosol cloud (up to 500 m downwind), and conducted validation tests from 1979 to 1981.

A TBM's insecticide spray cloud is initially a mix of droplets of various diameters. The mass median diameter of droplets released from a tank of fenitrothion emulsion is about 95 μm ; that is, half the mass (or volume) is in droplets smaller than that diameter, and half is in larger droplets (Tomney *et al.*, 1978). The general pattern is that the larger droplets settle out under the swath line, medium-diameter droplets impact within 500 m, and some of the smaller droplets may travel for miles. More than half the volume of active ingredient falls out within the first 70 m under the influence of aircraft vortex. Typically more than 80% of the volume falls out downwind within 500 m of the swath line, and about 90% within 1 km. However there is much variation around such average deposition percentages, according to variables of spray height, terrain, vegetative cover, weather and formulation. Leeward displacement of the swath increases with the height of the aircraft above the tree tops; so for parallel deposition of swaths it is important that pilots try to maintain the operational elevation of 30 m above the canopy (Picot and Kristmanson, 1980b).

The spectrum of droplet diameters at the generation point can be characterized by numbers of droplets and by their mass or volume; that spectrum governs subsequent droplet distributions in the air or on receptor surfaces. An emission with a droplet mass median diameter of 95 μm , has a numerical median diameter of around 32 μm ; that is, half the number of droplets produced have a diameter less than 32 μm . Thus a small fraction of the mass emitted accounts for a large fraction of the numbers emitted. The small mass which escapes 1 km downwind nevertheless contains a large percentage of the number of droplets emitted (Picot and Kristmanson, 1980b).

There is another complication; the reduction of droplet size by evaporation of water. The authorized emulsion formulation of fenitrothion contains 86% water. Droplets lose most of their water by evaporation in the first 10-20 sec (Kristmanson, personal communication, 1982). Evaporation reduces droplet diameter to about 58% of the generated diameter, and to about 20% of the volume. Thus the spectrum of droplets in drift is much smaller than that of droplets at emission, and their settling rate is correspondingly weaker. Droplets in oil formulation lose weight more slowly because the carrier is less volatile. Droplet mass is important because it profoundly effects the momentum of the flying droplet and its capacity to impact on obstacles such as foliage.

After evaporation of most of the water, flying droplets lose mass very slowly by vaporization of the active ingredient insecticide, the adjuvants and residual water. However the vapor so produced continues to be an air pollutant moving with the body of the aerosol cloud.

The Picot-Kristmanson model can be used to predict concentration in air of droplets at any height, and deposition on tree foliage and on the ground, at any distance downwind, as a function of time. It predicts that atmospheric drift beyond 100 m from the swath line will be greater with increase in aircraft height and reduction in wind speed. Biologists should note that the conifer canopy is an efficient filter for settling droplets, permitting little penetration to the ground. Field experiments in 1980 showed that for a fenitrothion emulsion spray generated by TBM, about 3% of the number of droplets deposited on the ground below forest cover within 100 m of the spray swath line (Picot and Kristmanson, 1980b).

The far-field drift model - transport beyond 1 km - is being developed by Crabbe et al. (1980a,b) of the Unsteady Aerodynamics Laboratory, National Research Council of Canada. It has been tested using results of field trials from 1979 to 1981. The tests suggest that turbulent weather (near neutral conditions when the inversion layer is breaking up) produces less drift than the non-turbulent flow conditions associated with early morning stability. In one field trial, 6% of the active ingredient was still airborne

7.5 km downwind under turbulent conditions, while 16% was still airborne under inversion conditions in which the suppressed levels of atmospheric turbulence reduced the turbulent transfer of drifting droplets into the forest. Evidently breezy weather induced faster deposition of droplets in the forest canopy. Those droplets found 7.5 km downwind were very small, 2-20 μm .

Both near-field and far-field models require further refinement and field validation, especially in relation to vortex behavior and vertical dispersion of the aerosol cloud.

Field tests were conducted in 1980 and 1981 during modelling development to estimate human exposure to drift at a range of downwind distances (Crabbe et al., 1980b). Field costs were funded mostly by Forest Protection Ltd. and in part by the New Brunswick Department of Health. The research was aimed at determining the mass of aerosol (droplets < 50 μm diameter) which might be inhaled by a man downwind of the spray in one day; such information is useful when establishing or adjusting buffer zone widths. Spray blocks consist of numerous parallel swaths, and each swath contributes to the total drift downwind beyond the block. However, close to the block boundary the inhalation potential is largely set by the distance to the nearest swath, whereas 1 km downwind of the boundary, the number of swaths becomes more important (Crabbe et al., 1980b).

Their results showed that exposure to inhalable aerosol 300 m downwind may be about one-half of the exposure at the swath line in a multiple swath operation. Droplet size diameter was quickly reduced by settling and evaporation; 500 m downwind, most of the mass of the aerosol cloud was composed of droplets around 4 μm diameter. At any one place in the near-field drift zone, exposure to the aerosol cloud lasted only 20 to 30 min. However the vapor plume from deposits on foliage continued and increased during the warm hours of the day, and persisted for at least 10 h post spray. The data indicated that a person 1 km downwind of a multiple swath operation might inhale up to 2.4 μg of fenitrothion during a 10 h work day immediately post-spray. Thus atmospheric pollution by aerosol drift is light and brief, while exposure to vapor is potentially longer and stronger.

The chemical stability of drift of fenitrothion and aminocarb is also of concern. Research by Wiesner et al. (1981) has shown that no photo-degradation of either material occurs in the aerosol phase during the first 5 min of drift. They determined that the half life of the vapor phase in a laboratory photoreactor is 61 min for fenitrothion, and 38 min for aminocarb; thus there is some possibility of detectable degradation products in the vapor plume. The toxicological significance of such chemical change at these low dosage rates is unknown.

Meanwhile, the federal departments of Agriculture and Health & Welfare are developing models of worst case exposure to pesticides under various occupational scenarios (C.A. Franklin, personal communication, 1980). The model (introduced in 1979) for the bystander in a forest spray shows that the main pathway to exposure is through the skin - contamination by impacting or smeared droplets. The expected maximum deposition on the skin of a fully clothed adult standing under the swath line and unprotected by the foliate canopy would be around 0.7 mg. Ingestion intake (by swallowed interception

of inhaled aerosol) might add another 0.35 mg, while deeply inhaled fenitrothion aerosol could add 0.035 mg; in total about 1 mg of fenitrothion intercepted during the 10 min passage of the spray cloud. These estimates are based on the relatively crude information on spray cloud behavior available in 1979; the exposure values are likely to be substantially modified by new information generated by current sophisticated methodology (Crabbe *et al.*, 1982). The application of Crabbe's model of diminishing concentrations downwind would show far lower exposures by all three pathways at 1 km beyond the swath boundary.

The ecological effect of drift is very difficult to assess. While it can be shown that drift may kill insects, it is hard to prove that such mortality has a significant effect on species population dynamics, or on the stability of communities or ecological processes, or on the productivity or resources.

Indicator insect species can provide sensitive bioassays of drift. Drop-trays placed under trees can be used to collect insects poisoned by drift insecticides. Good indicators in spruce and fir stands as far as 1200 m downwind are budworm larvae, adult parasitic hymenoptera, and foraging ants. However, the rate of drop of moribund insects is not always closely correlated with the rate of insecticide deposit. There are occasions when susceptible insects are not in a vulnerable habitat or at a vulnerable phase of behavior, and heavy deposit does not produce heavy kill.

Honeybees and wild bees such as halictids and andrenids are also exposed to downwind drift, perhaps to a range of 3 km in the case of blueberry fields (Wood and Stewart, 1976). Insecticide-induced reduction in population density has been shown by surveys, before and after drift, using the number of bees per unit of time visiting a quadrat of vegetation as the criterion of abundance (Wood, 1979). Bee susceptibility may be due to airborne droplets, vapor from deposits, or to deposit residues on flowers and pollen. It is very difficult to identify crop losses ascribable to any bee mortality because productivity is subject to so many other factors.

Evidence of drift may also be inferred from the analysis of residues of insecticide in coastal bivalves as far as 50 km from a spray block (Mallet, 1980). Evidently mussels may bio-accumulate fenitrothion from faint residues in estuarine and coastal waters, most probably derived from rain scavenging of far-field aerosol clouds. Insecticides have been detected in rain water up to 85 km from the closest possible source (Pearce *et al.*, 1979).

Thus there is large body of theoretical and field knowledge about insecticide drift relating to insecticide accountancy. More information is needed on the influence of weather, terrain, foliage type and wind-fields on aerosol and vapor transport. The practical goal is to learn how to use less insecticide with greater efficacy and less drift, by utilizing knowledge of emission spectra, favorable spray weather, and droplet impaction efficiency.

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1980 and 1981 PESTICIDE STUDIES:

MONITORING OF OFF-TARGET FALLOUT DURING SPRUCE BUDWORM SPRAY PROGRAMS

by

H.S. Bailey and P.E. Belliveau

Water Quality Branch
Inland Waters Directorate
Environment Canada

There has been a continued interest in determining the nature and extent of pesticide drift, outside of the target zones, resulting from the Spruce Budworm Spraying Operation. In 1978, Pearce, Brun, and Witteman studied this off-target drift and showed that small amounts of fenitrothion could be detected in rainwater at points as far as 85 km from the nearest spray zone (Pearce *et al.*, 1979). Using the same methodology, Pearce and Brun studied aminocarb in 1979 and found similar results. (The report for 1979 study is pending.) In 1980, the incidence of dry fallout versus rain washout was studied, whereas in 1981, the sequence of deposition during a rain event was monitored.

The aim of the 1980 pesticide study was to determine the relative size of the dry fallout and washout fractions of pesticides deposited on non-target areas. The 1981 study had two objectives: (1) to determine the extent of pesticide drift; and (2) to determine the concentration of pesticides in sequentially fractioned rain events.

During the 1980 program, duplicate bulk and event precipitation collectors were placed in two non-target areas: Fundy National Park at Wolfe Lake and Camp Forces Base (CFB) St. Margarets. The bulk precipitation collectors were maintained continuously open to collect both dry fallout and rain. The event precipitation collectors were opened only when it rained.

In 1981, sequential samplers capable of collecting approximately 3000 mL during a rainfall event of 10 mm were placed in Kouchibouguac National Park near the Information Bureau and also at Fundy National Park at Wolfe Lake. Duplicate bulk collectors were also employed at each site. The collectors were installed approximately a week before the spray and remained in place for a week after the spray operation.

The bulk, event and sequential collectors utilized XAD-4 resin columns as a pesticide trap. These columns were retrieved for fenitrothion (1980) and aminocarb (1980) analysis after every rain event of at least 10 mm.

In 1980, a total of 20 samples from CFB St. Margarets and 16 samples from Fundy National Park were analyzed for fenitrothion and aminocarb, and the results indicated one positive value (near detection limit) for fenitrothion from the CFB St. Margarets site and four positive values (of

about 0.1 ppb) for fenitrothion from the Fundy site. Equivalent amounts were found in both bulk and event samples which indicate that rain washout was the method of deposition.

During the 1981 program, a total of 36 samples from Kouchibouguac National Park and 44 samples from Fundy National Park were analyzed. From a preliminary scan of the raw data, 28 Kouchibouguac samples had positive values ranging from trace to 1.0 ppb. At Fundy National Park, 15 samples exhibited positive values ranging from 0.07 to 2.9 ppb. The raw data from the sequential collectors suggest that 60-90% of the fenitrothion is washed out in the first 10 mm of the rain event.

A combined report for the 1980 and 1981 studies is now in progress and should be completed by April 1982.

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A STUDY OF BUFFER ZONE EFFECTIVENESS CONDUCTED IN CONJUNCTION WITH THE 1980 SPRUCE BUDWORM SPRAY

by

W.R. Ernst, G.R. Julien, K.G. Doe, W.R. Parker, and W.G. Pelly
Environmental Protection Service
Environment Canada

Field studies, conducted jointly with Environment New Brunswick, indicated that a 400 m no-spray "buffer zone" surrounding a small lake was sufficient to reduce the incidental deposit of the spray formulation on the lake's surface by 92% and 80%, after first and second sprays, respectively, when compared with a similar lake which had no buffer zone. This observation was made after operational applications of fenitrothion at 210 g a.i./ha in a water formulation using TBM aircraft equipped with TEE jet nozzles (11010 tips). A comparison of fenitrothion concentration in surface waters of the two lakes after the first application indicated a 56% reduction due to the buffer zone.

This study and other aspects of the environmental monitoring of the 1980 New Brunswick spruce budworm spray program by the Environmental Protection Service, Atlantic Region (Environment Canada) are described in the EPS Surveillance Report EPS-5-Ar-81-3.

DURATION OF FENITROTHION SPRAY CLOUD

BY

G.W. Wood

Agriculture Canada Research Station

The duration of fenitrothion spray clouds within and near three separate blocks of the 1981 budworm spray program was monitored with small portable air samplers. The sampler consisted of a 40 mL plastic funnel (12.6 m² surface area) containing 6 g of Amberlite XAD-2 resin through which ambient air was drawn by means of a small diaphragm pump (Brailsford) at a flow rate of about 3 L per min. At each site the sampler was mounted on a stand 1 m above the ground and consecutive five min air samples were taken for one h after the nearest pass by a spray plane.

Fenitrothion was extracted from the XAD-2 resin in two steps, first with a hexane-acetone (1:1) solvent and then with acetone. The fenitrothion was then reduced to 1 mL at 40°C in a roto-evaporator, and analysed by gas liquid chromatography on OV-17 liquid phase at 200 C by a flame photometric detector.

No spray plane passed directly overhead at any of the sites so all collections of insecticide in the samplers resulted from drifting spray clouds. The minimum interval of time between the pass of the nearest aircraft and collection of fenitrothion in a sampler was 5 min and the maximum interval was 25 min. The latter reading occurred within a block where spray booms had been shut off for about 1 km to avoid spraying a small river. This was an evening spray carried out under calm conditions.

Minimum duration of a primary spray cloud (the first to pass over the sample site) was 5 min, and this occurred at a site 1 km downwind from the nearest flight line. Wind velocity at ground level was about 2 km/h. Maximum duration of a primary spray cloud was 15 min and this occurred under calm conditions. At all sites, there was also a second spray cloud which passed by 20 to 40 min after the primary one. Amounts of insecticide collected in the secondary spray cloud were much less than in the primary cloud and could have drifted from any part of the spray block.

The maximum concentration of insecticide in primary spray clouds ranged from 90.3 to 441 µg/m³ for any 5 min sample of air. The latter reading was taken at a site 1 km downwind from the spray block while the wind velocity was approximately 2 km/h. The highest concentration for a secondary spray cloud was 65.2 µg/m³.

DISTRIBUTION, PERSISTENCE AND FATE OF MATACIL^R

FORMULATIONS IN A STREAM ECOSYSTEM

by

K.M.S. Sundaram

Forest Pest Management Institute
Canadian Forestry Service
Environment Canada

Newly introduced aminocarb flowable (Matacil^R 180F), a suspension concentrate formulation, was applied to different segments of a stream near Sault Ste. Marie, Ontario at intervals of time as (i) a water emulsion (180FE) and (ii) as an oil formulation (180FO) along with (iii) the conventional oil-soluble concentrate (180D) in I.D. 585.

Aminocarb residues disappeared very rapidly (within a few hours after injection) from the stream water primarily due to dilution; the rate of loss of the chemical was directly proportional to stream discharge regardless of formulation. In terms of all three formulations, sediment samples contained extremely low but detectable levels of aminocarb for a short time (maximum 20.2 ppb at 5 min post-spray with 180FE) and disappeared to trace levels (3 ppb) within 30 min.

The emulsion formulation persisted in low amounts (0.1 ppb) for 1 h in water, and in sediments for a longer time (3 ppb for 1 h) compared to the two oil formulations (180F and 180D) due to the presence of hydrophilic surfactant Atlox 3409 F^R.

Samples of hatchery-reared rainbow trout fingerlings were held in cages in the treatment streams. The fish exposed to the emulsion formulation accumulated aminocarb. However, in these fish, and fish from streams treated with the other formulations, the concentrations found were low (maximum 127 ppb on the basis of wet weight) and not considered to be of toxicological significance. No mortality or noticeable behavioral changes in fish were observed during the experimental period.

DISTRIBUTION, PERSISTENCE AND FATE OF MATACIL^R

FORMULATIONS IN A FOREST ECOSYSTEM

by

K.M.S. Sundaram

Forest Pest Management Institute
Canadian Forestry Service
Environment Canada

Three spray formulations, i.e., newly introduced aminocarb flowable (Matacil^R) 180F) as an aqueous emulsion (180FE), and in Shell I.D. 585 (180FO,

an oil formulation), and the conventional oil-soluble concentrate containing nonylphenol diluted with Shell Sunspray 6N^o oil (180D), were applied separately to different plots twice at 70 g a.i./ha by means of a fixed-wing aircraft to a mixed coniferous forest near Bathurst, N.B.

Distribution, persistence and fate of aminocarb residues in fir foliage, forest litter and soil collected at different intervals of time, were studied by gas/liquid chromatography (GLC) analysis after solvent extraction and necessary cleanup.

Residues in balsam fir foliage were usually small but varied according to the formulations sprayed. Usually, higher residue levels were found with the oil formulations 180D and 180F0 as compared to the water formulation 180FE. With all three formulations, the active material was lost rapidly. The active material had a low half-life and residue levels declined as a curvilinear function with time.

Aminocarb residue levels were extremely low in soil as compared to forest litter and persisted longer at detectable levels in the latter.

The additives in the formulation played a significant role in droplet spectrum and deposition characteristics of the material.

Findings from this study agree with previous findings (Sundaram *et al.*, 1976), thereby confirming that the aminocarb insecticide was lost rapidly and has low persistence in some of the forestry substrates studied.

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A CHEMICAL RESIDUE SURVEY IN RELATION TO THE 1980 SPRUCE BUDWORM SPRAY PROGRAM

IN NEW BRUNSWICK - A PILOT PROJECT

by

V.N. Mallet

Département de Chimie
Université de Moncton

This report contains data resulting from the analysis for fenitrothion of 465 water and air samples collected in connection with the 1980 spruce budworm spray program in New Brunswick. Water sampling was done in the Nepisiquit River near Bathurst (three sites) and two brooks, namely Location 44 and Little Elbow River (one site in each brook) feeding into the Nepisiquit River.

Another location along Route 430 near Sevogle Airstrip consisted of a small "beaver pond" (one site). Water was also sampled in the Canaan River and two brooks feeding into it, namely East Brook Canaan and South Brook Canaan (one site at each location). A third location was the Turtle Creek Reservoir of the City of Moncton (one site).

Air was sampled at three sites, one at Sevogle Airstrip, another where Route 430 crosses the Nepisiquit River, and a third on campus at Université de Moncton.

Fenitrothion was usually detected in water when spraying occurred in the immediate area of the sites. The maximum level that was detected was 20.0 ppb and persistence of fenitrothion was usually limited to a few days, except in the "beaver pond" where it was detected for 18 consecutive days. Amino-fenitrothion was also detected with a maximum concentration of 8.0 ppb. Pre-spray samples and those collected approximately one week after spraying had ceased in the immediate area did not contain any trace of either fenitrothion or aminofenitrothion.

Fenitrothion was detected only occasionally in air samples - the maximum being 1.2 ng/dm³. Although there is no ambiguity as to the origin of fenitrothion, the presence of aminofenitrothion in air samples cannot be explained as yet.

In general, the results indicate that contamination was low in sprayed areas of the Province and practically non-existent in non-target areas.

A more detailed description of this survey is given in the report entitled "A chemical residue survey in relation to the 1980 spruce budworm spray program in New Brunswick" by Victorin N. Mallet, Report No. 80-CP-18, Environment New Brunswick, Fredericton, N.B., September 30, 1980.

A FENITROTHION RESIDUE SURVEY IN RELATION
TO THE 1981 SPRUCE BUDWORM SPRAY PROGRAM

IN NEW BRUNSWICK

by

V.N. Mallet

Département de Chimie
Université de Moncton

The study summarized here is based on data from the analysis of 136 samples of water, air, foliage, soil litter, and sediment for the presence of fenitrothion and some known degradation products, namely hydroxymethylfenitrothion, S-methylfenitrothion, fenitrooxon, aminofenitrothion, formylfenitrothion and nitrocresol (3-methyl 4-nitrophenol). The study was carried out in the context of the 1981 spruce budworm spray program in New Brunswick to

determine the concentrations of fenitrothion and these degradation products in the environment.

Water from the Canaan River area was sampled and analysed to allow comparison with samples taken from the same sites in 1980. The results are very similar to those of the 1980 survey, i.e., the quantities of fenitrothion detected were very small (maximum of 1.3 ppb) and did not persist beyond a few days post-spray.

The 1981 survey also included sampling and analysis of water, air, soil litter and sediment from the Aboujagane River area. Water samples contained low levels of fenitrothion which did not persist beyond a few days. Air was sampled for eight consecutive days (24 h sampling) and traces of fenitrothion were detected on two occasions (0.08 and 0.04 ng/dm³). Fenitrothion was also detected in pre-spray and post-spray samples of other substrates, particularly foliage (maximum of 0.53 ppm).

Aminofenitrothion, the only degradation product detected, was found in water samples from the Canaan River area. The amounts detected were less than 1 ppb.

POSSIBLE OCCURRENCE OF A FENITROTHION-
DERIVED NITROCRESOL IN NEW BRUNSWICK WOODCOCK

by

P.A. Pearce

Canadian Wildlife Service
Environment Canada

During an investigation in 1978 of apparent ocular anomalies in New Brunswick woodcock, birds were screened for pesticide contamination. Five composite samples of five birds and an additional 25 individual woodcock were analysed at the Ontario Research Foundation (ORF) for organochlorine compounds, and for fenitrothion and some of its breakdown products. The nitrocresol 3-methyl-4-nitrophenol was determined by extraction with ether/HCl, partitioning between hexane and acetonitrile, methylation by diazomethane and analysis by gas-liquid chromatography using an electron capture detector. Low concentrations - up to 0.48 ppm (whole body, wet weight) - of that fenitrothion derivative were found, but not confirmed, in many of the samples.¹ Additional woodcock collected in 1980 from fenitrothion spray zones are being analysed at New Brunswick Research and Productivity Council laboratories. Problems with analysis involving interferences and instrumentation have caused a delay in completion of the work. The biological significance of the presence of the nitrocresol is

¹Details of analytical methodology employed at ORF are given by Reynolds (1979).

not at present known. A more detailed description of the study of woodcock eye anomalies is given in the manuscript report "Apparent ocular anomalies in American woodcock *Philohela minor*" by E. Broughton, P.A. Pearce, L.M. Reynolds, and N. Garritty, which is available from the Canadian Wildlife Service.

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FENITROTHION ACCUMULATION BY PLANTS AND INVERTEBRATES IN TWO EXPERIMENTALLY-SPRAYED STREAMS IN NEW BRUNSWICK

by
A.J. Sosiak

Montreal Engineering Company, Limited
(Present affiliation: Monenco Consultants)

Recent studies have determined that the forest spray fenitrothion may persist in aquatic plants after the spray application (Moody *et al.*, 1978; Morrison and Wells, 1981). Certain aquatic invertebrates consume algae, bryophytes and other aquatic plants, and depend more on such material in the spring (Chapman and Demory, 1963) when forest spraying for spruce budworm usually occurs. Fenitrothion residues in aquatic plants may have toxic effects on herbivorous invertebrates, waterfowl or mammals that feed on them. Furthermore, several fenitrothion degradation products can be at least as toxic as the parent compound (Miyamoto, 1977; Zitko and McLeese, 1980).

No previous study has determined the levels of residues of fenitrothion or its degradation products in stream plants in New Brunswick. A total of nine species of aquatic plants and four stream invertebrates were therefore sampled in May and June 1981 before, and for seven days after, experimental spraying with fenitrothion (Montreal Engineering Company, Limited, 1981). Manzer Brook received fenitrothion in emulsifiable concentrate formulation applied by backpack mistblower, while Otter Brook received fenitrothion in 585 oil (see summary by Eidt and Mallet, p. 76). Both plants and animals were analysed by gas chromatography for fenitrothion, 3-methyl-4-nitrophenol, fenitrooxon and aminofenitrothion. Stream water samples were also collected where the plants and animals were sampled. One pre-spray water sample contained traces of fenitrothion, possibly because of drift from forest spray operations. The concentration of fenitrothion in water samples increased after spraying to a maximum of 4.1 in Manzer Brook and 11.3 µg/L in Otter Brook within six h of spray application. In both streams, the fenitrothion concentration decreased to less than 1% of the peak concentration 24 h after spraying.

Fenitrothion residues were found before spraying in the liverwort Solenostoma sp., swamp candle (Lysimachia terrestris), manna grass (Glyceria borealis), and the green alga Draparnaldia sp., and in the invertebrates Simulium sp., Heptageniidae, Neophylax sp. and Pycnopsyche sp. All plant and animal samples contained post-spray fenitrothion residues. Highest concentrations in this study were found in the liverwort Solenostoma sp., which had peak fenitrothion concentrations of 2.94 and 9.0 µg/g (dry weight) in Manzer Brook and Otter Brook, respectively. Relatively high concentrations of fenitrothion remained in this organism (compared to the others) seven days after spraying. Furthermore, its bioaccumulation ratios were the highest yet reported for an aquatic plant exposed to fenitrothion. The highest fenitrothion residue levels which were detected in the aquatic moss Fontinalis sp., slender spikerush (Eleocharis acicularis) and manna grass, occurred six h after spraying. However, residue levels in water-mat (Chrysosplenium americanum), the liverwort Riccia sp., swamp candle, Draparnaldia sp. and all four invertebrate taxa peaked later in the sampling program. The highest fenitrothion residue level detected in an invertebrate was 10.0 µg/g, measured in Simulium sp. 24 h after spraying.

Fenitrothion residues in all organisms except Solenostoma sp. had decreased markedly after seven days. The degradation product 3-methyl-4-nitrophenol was found in two plant samples 6 h after the post-spray sampling program, but not thereafter. One post-spray Heptageniidae sample also contained 3-methyl-4-nitrophenol. Neither fenitrooxon nor aminofenitrothion were found in any sample.

Based on published information, the concentrations of fenitrothion and the three degradation products which were found in the plant and invertebrate samples are not likely to cause acute lethal effects on fish, birds or mammals that ingest them. However, further studies are needed to determine whether these residues could have sublethal effects on vertebrates or any effects on aquatic invertebrates.

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FREQUENCY OF FOREST SPRAYING IN NEW BRUNSWICK

by

D.C. Eidt

Maritimes Forest Research Centre
Canadian Forestry Service
Environment Canada

Because of the changing patterns of spruce budworm hazard to the forest, the distribution and degree of overlap of spray blocks from year to year also varies. Because some insecticide residues (e.g., DDT) and environmental perturbations may persist, it is important to appreciate the extent of past repeat spraying and the chances of future repeat spraying. Eidt and Fisher (1982) addressed this question and, based on a study of the New Brunswick spray record, estimated the chances of respraying in the next two years.

Barring substantial changes in budworm infestation levels or spray strategy, they estimated the chances of a particular area being sprayed in 1981 and resprayed in 1982 are between 10 and 20% (depending on the total area sprayed in 1982), and again in 1983, between 5 and 10%.

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STUDIES OF CANDIDATE INSECTICIDES

ENVIRONMENTAL IMPACT STUDIES ON SEVIN-2-OIL^R (carbaryl) AND RELDAN^R

(chlorpyrifos-methyl) IN NEW BRUNSWICK IN 1980

by

P. Kingsbury, S. Holmes, R. Millikin and S. Szeto

Forest Pest Management Institute
Canadian Forestry Service
Environment Canada

Sevin-2-Oil^R and Reldan^R were applied experimentally in 1980 to two 400 ha spray blocks located near Allardville in Gloucester County, New Brunswick. The purpose of these spray trials conducted by the Forest Pest Management Institute was to assess the efficacy and environmental impact of the two insecticides at application rates proposed for spruce budworm control.

Sevin-2-Oil applied twice at 280 g a.i./ha had no significant adverse effects on either forest songbirds or wild pollinators, and only a slight knockdown effect on non-target terrestrial arthropods. Carbaryl residues as high as 313.7 ppb and 122.6 ppb were detected in stream water immediately after the first and second applications respectively. The residues declined rapidly but were still detected (0.9 ppb) up to 10 days after the completion of spraying. Although both treatments resulted in disruptions in the normal diurnal drift pattern of aquatic invertebrates, the overall effect on benthic invertebrate populations was negligible. Analyses of brook trout and slimy sculpin stomach contents indicated that availability of food was not significantly reduced. No mortality was recorded among native brook trout held in cages in treatment streams for up to 10 days after the second application.

Reldan was applied twice at 70 g a.i./ha. Knockdown of non-target terrestrial arthropods was slight. Forest songbird populations remained stable throughout the study period, with little evidence of territorial disruption. Peak levels of chlorpyrifos-methyl in stream water were 88 ppb, 30 min after the first application, and 212 ppb, 5 min after the second application. These decreased to non-detectable levels within 42.5 h and 99 h of application, respectively. Chlorpyrifos-methyl residues averaging 29 to 34 ppb (on a wet weight basis) were detected in wild brook trout within a few days of each application, but had fallen to trace amounts (3 ppb) after a week. Although a 19-fold increase in aquatic invertebrate drift was noted following the second application, no significant depletions in the benthos attributable to spraying were found by three different bottom sampling techniques used. The diets and condition coefficients of brook trout and slimy sculpins were not significantly altered as a result of the insecticide applications, and there was no mortality of native brook trout and Atlantic salmon parr held in cages in the treatment stream for up to 10 days after the second application.

Complete descriptions of the environmental impact studies conducted in connection with the Sevin-2-Oil and Reldan experimental spray trials in New Brunswick in 1980 are given by Holmes *et al.* (1981) and File Report No. 13 (A preliminary report on the effects of a split application of Reldan on aquatic and terrestrial ecosystems) of the Forest Pest Management Institute, Canadian Forestry Service, Sault Ste. Marie, Ontario.

REFERENCE

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RESIDUES OF CHLORPYRIFOS-METHYL IN BALSAM FIR FOLIAGE FOREST LITTER, SOIL, STREAMWATER, SEDIMENT AND FISH TISSUE AFTER DOUBLE AERIAL APPLICATIONS OF RELDAN^R

by

K.M.S. Sundaram

Forest Pest Management Institute
Canadian Forestry Service
Environment Canada

Chlorpyrifos-methyl was applied twice at 70 g a.i./ha by means of a fixed-wing aircraft to a mixed coniferous forest near Allardville, New Brunswick. Residue in balsam fir foliage was highest (1 ppm wet weight) one h after spraying and rapidly declined to about 30% of this level within one day, but persisted at a very low level (0.03 ppm wet weight for 125 days). Current year's foliage contained a higher level of residue than old foliage. Chlorpyrifos-methyl persisted longer in forest litter than in soil. After 125 days, trace amounts (6 ppb wet weight) were still found in litter, but were not detected in soil. In stream water, the residue dissipated very rapidly; more than 90% disappeared 3 h after the second application and the residue was not detected after 4 days. A small amount of residue (0.1 ppm wet weight) was present in the sediment and persisted for 10 days. Although brook trout and slimy sculpin captured in the stream within 3 days of the second application contained residues (0.05 ppm fresh weight), none was detected in any fish captured, 9 and 47 days later.

More detailed description and discussion of the results can be found in Sundaram (1980) and Szeto and Sundaram (1981).

REFERENCES

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ENVIRONMENT IMPACT ASSESSMENT OF EXPERIMENTAL PERMETHRIN

APPLICATIONS IN NEW BRUNSWICK, 1980

by

P. Kingsbury and D. Kreutzweiser

Forest Pest Management Institute
Canadian Forestry Service
Environment Canada

Experimental permethrin applications were studied in York County, New Brunswick in 1980 to assess environmental impact on selected aquatic and terrestrial organisms. Permethrin, at the rate of 17.5 g a.i. in 1.46 L of formulation/ha, was applied from a Cessna Ag-Truck to two 600 ha blocks (one a single application and the other a double application with a four-day interval) located in the Young's Brook watershed near the hamlet of Nashwaak Bridge, approximately 35 km north of Fredericton.

The accumulation and persistence of permethrin residues in water, fish, crayfish and sediment were determined by the Chemistry Department of Chipman Incorporated, in Stoney Creek, Ontario. Pesticide effects on aquatic macroinvertebrates within and below the single and double application blocks were monitored by the Environmental Impact Section of FPMI, and by the Maritimes Forest Research Centre at Fredericton. In response to concerns of possible hazards to juvenile Atlantic salmon in the streams, Montreal Engineering Co. Ltd. (MECo) of Fredericton was awarded a research contract and, with the assistance of FPMI personnel, conducted studies to determine lethal and non-lethal effects of the permethrin applications on indigenous fish species and caged Atlantic salmon sac-fry, and crayfish. In addition to those studies conducted by MECo, the diets of native fish in the exposed portions of the streams were analyzed to determine possible changes in feeding activity in response to the pesticide impact. Pesticide-induced knockdown of arboreal and flying invertebrates from pin cherry and balsam fir foliage in the treatment blocks was also measured after each application.

The complete results of these studies are forthcoming in a Canadian Forestry Service Information Report FPM-X-52 entitled "Permethrin in New Brunswick salmon nursery streams" which will be published by the FPMI early in 1982.

PERMETHRIN RESIDUES IN FOREST AND STREAM COMPONENTS

by
D. Kreutzweiser^a and G. Wood^b

^aForest Pest Management Institute
Canadian Forestry Service
Environment Canada

^bChipman Inc.

Residual permethrin in stream water from the single application block (described by Kingsbury and Kreutzweiser on p.112) reached a post-spray maximum of 0.23 ppb immediately after the application but declined to non-detectable levels (0.01 ppb) within six h. Water samples collected from several sites within the double application block described above peaked at 0.13 to 0.31 ppb, after the initial spray but fell to non-detectable levels in all but one location within 24 h. The second application resulted in somewhat higher permethrin residues in stream water with peak levels of 0.22 to 0.96 ppb and a persistence in low concentrations (0.04 ppb) at most sample sites for at least 48 h. Samples from a section of stream 0.2 to 1.4 km below the double block contained measurable quantities of permethrin after both applications but did not attain peak levels comparable to, nor persist as long as, those in the block itself.

Accumulation of residual permethrin in fish sampled from the single application block ranged from non-detectable levels (0.005 ppm) to 0.020 ppm (on a wet weight basis) three days after the application. From the 28-day post-spray collection, only brook trout contained measurable residues (0.010 ppm), while no pesticide residues were found in any of the fish sampled 73 days after the application. Levels of from 0.020 to 0.095 ppm permethrin were detected in the tissue of brook trout and juvenile Atlantic salmon collected in the double block up to 25 days after the second application. No permethrin residues were found in samples of slimy sculpins or American eels, and by 2 1/2 months post-spray, no residues were detected in any fish samples from the double application block.

Crayfish exposed to the application in screened cages placed in the single and double application blocks and collected 13 days after the second application to the double block, contained no detectable concentrations of permethrin.

The amount of residual permethrin accumulated in stream sediments was minimal. One of a total of 15 sediment samples taken from the double block and two of a total of nine samples from the single application block contained permethrin, with 0.024 ppm the highest residue found.

Permethrin residues in forest litter from the double block attained peak accumulations as high as 0.157 and 0.750 ppm one to four days after the second application. Residues in the litter persisted to the end of the sampling period (68 days post-spray) at concentrations ranging from 0.027 to 0.037 ppm.

THE IMPACT OF PERMETHRIN ON AQUATIC INVERTEBRATES

by

D.C. Eidt

Maritimes Forest Research Centre
Canadian Forestry Service
Environment Canada

Aquatic invertebrates were monitored in a stream system treated with permethrin by FPMI in early June 1980. Two 600 ha treatment blocks were used, one block sprayed once at 17.5 g a.i./ha, and the other twice at 17.5 g a.i./ha. The rates were selected because they previously had been shown by FPMI to be the lowest efficacious rate against the spruce budworm. The block with the single application included about 1/10 the drainage area of a stream and the stream was sampled near its outflow from the block. The block with the double application included about 1/25 of the drainage area of another stream which also received the drainage from the single treatment block. Benthos samples were taken near the outflow from the double treatment block, 1.4 km downstream, 4.2 km downstream, and, for control, 2.2 km upstream of the block.

In both blocks, large numbers of dead and distressed invertebrates were caught in drift nets on spray days, demonstrating a high acute toxicity. A measurable decline in numbers of aquatic invertebrates did not occur in the stream in the single-application block, but population increases seen in the control stretch did not occur either. Biomass declined slightly and persisted until late fall. No taxon, at the level studied, disappeared from the fauna, but many became scarce. Black flies, for example, virtually disappeared.

In the double treatment block, massive drift of dead and distressed aquatic insects occurred after each spray, followed by a decline in numbers of invertebrates in stream bottom samples. Biomass was drastically reduced and persisted until late fall. The total number of taxa and their diversity were greatly reduced for two months; the change in diversity was largely manifested by a predominance of midge larvae. Black fly larvae virtually disappeared until fall. These results are consistent with those of Kingsbury and Kreutzweiser (1980) and antecedent work by FPMI and others. Effects on aquatic invertebrates were seen 1.4 km downstream and minor effects on drift in a control stream 1 km downwind of the double treatment block.

Recovery of benthos was substantial, but not complete by October 1980. One year after the pretreatment sample, benthos populations and biomass were much higher than pretreatment levels at all stations, but diversity was low in both treatment blocks, where midges were relatively more abundant.

Recovery of benthos was slow, considering that the upstream area available for potential colonizers was extensive. Had the entire watershed been sprayed, recovery probably would have been much slower, and depletion effects would be expected to carry over into the next year. The effects of permethrin on aquatic invertebrates, in this experiment, were

more severe than those of any currently-used spruce budworm insecticide including carbaryl, which as Courtemanch and Gibbs (1980) have demonstrated, has serious effects when used extensively.

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EFFECTS ON JUVENILE ATLANTIC SALMON AND CRAYFISH

OF FOREST SPRAYING WITH PERMETHRIN

by
A.J. Sosiak^a

Montreal Engineering Company, Limited

(^bPresent affiliation: Monenco Consultants)

As described elsewhere in this section (p.112), in June 1980, the Forest Pest Management Institute of the Canadian Forestry Service tested the synthetic pyrethroid permethrin for spruce budworm control in New Brunswick. One 600 ha forest block was sprayed with a single application of 17.5 g a.i./ha permethrin; a second such block was sprayed with a double application. During this trial, Montreal Engineering Company, Limited conducted studies on the mortality of 0+ Atlantic salmon and crayfish held in cages at sprayed and unsprayed sites (Kingsbury, 1981). Stream fish population densities and growth rates were also estimated.

Total mortality was less than 10% at each site during 11 days after the initial spray application. Therefore, the permethrin applications did not appear to have acute lethal effects on 0+ salmon. Furthermore, there were no differences in the behavior or appearance of 0+ salmon which could be attributed to spraying. There was little mortality in any of the crayfish cages until after the second spray application. Thereafter, higher mortality occurred in two cages in the double application block than at other sites, but the difference was not statistically significant when tested using a contingency chi-square test. Some observations on caged crayfish suggested behavioral changes after spraying. Effects of permethrin on crayfish behavior and survival should be further investigated.

Salmon parr decreased in abundance (Zippin population estimates) between May and July at the site furthest downstream in the double application block, while population densities at the single application and unsprayed sites were relatively stable. Fewer marked (adipose fin-clipped) parr were recaptured in July at sites in the double application block than at other sites. By September, salmon parr population densities at sites in the double application blocks were similar to those before spraying. The growth rates of 1⁺ and 2⁺ salmon parr were much lower at one site in the double application block than at unsprayed sites for the period stretching from May to July, and 1⁺ and 2⁺ parr weight at sprayed and unsprayed sites differed significantly (ANOVA) in July, after spraying. During the July-September period, parr growth rates were higher at the same double application site than at the unsprayed sites. In September, only 1⁺ parr differed significantly in weight between sprayed and unsprayed sites. These results suggest that double (but not single) applications of permethrin at 17.5 g a.i./ha can temporarily reduce juvenile Atlantic salmon population density and growth rate. These effects may have resulted from changes in food supply, as benthic invertebrates were markedly reduced in the double application block (Kingsbury, 1982).

REFERENCE

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EFFECTS OF PERMETHRIN ON FISH FOOD ORGANISMS AND

THEIR UTILIZATION BY NATIVE FISH

by

D. Kreutzweiser
Forest Pest Management Institute
Canadian Forestry Service
Environment Canada

An analysis of Surber samples collected in the single application permethrin block (described above by Kingsbury and Kreutzweiser on p.112) indicated that negligible changes in bottom fauna resulted from the treatment. The impact of the application on benthos in the single block was considerably less than that documented from previous single or initial applications, probably because of the comparatively light deposit measured in the block and the brief exposure (less than six h) of aquatic invertebrates to relatively low concentrations (maximum 0.23 ppb) of permethrin in the stream.

Both permethrin applications to the double block resulted in depletion of benthic invertebrates collected in Surber samples. The greatest impact was on Ephemeropterans, Plecopterans, and Tricopterans, with post-second spray numbers ranging from 65 to 82% below the mean pre-spray levels. The response of bottom fauna populations 1.4 km downstream from the double block to the permethrin applications was similar to that demonstrated in the block itself. Disturbance of benthos at the 4.2 km downstream station was much less apparent; only a slight reduction in numbers was found.

Recovery of benthos populations in the affected areas was evident within one month post-spray and virtually complete within 3½ months, although certain organisms, especially Ephemeropterans and Plecopterans, did not attain the late season high levels reached in the single application and control streams.

Immediately following the permethrin applications to the single and double blocks, slight increases in the composition and volume of food organisms in stomachs of juvenile Atlantic salmon indicated a certain degree of opportunistic feeding on pesticide-affected invertebrates that were apparently either in the drift for longer periods of time than normal or less capable of avoiding predation than normal. The subsequent post-spray feeding pattern was similar to that of juvenile salmon in the upstream control except that an early season decrease in the selection of Ephemeroptera nymphs was noticeably more pronounced in both application blocks after the permethrin treatments than in the control during the same period. This may reflect the reductions in Ephemeroptera populations that were especially evident in the double block following the applications. Stomach content analysis of 2⁺ salmon in both treatment streams indicated a comparatively greater reliance on terrestrial insects than that demonstrated by the control salmon, suggesting that an alternative food source was being pursued as benthic organisms became more difficult to obtain after the applications.

Brook trout in both treatment streams showed much greater opportunistic feeding on pesticide-affected invertebrates than did salmon parr in the same area. During a period of from one to 2½ months after the applications, brook trout in the double block became almost impossible to collect despite an extensive electro-fishing effort throughout virtually the entire section of stream. A possible explanation is that brook trout, in competition with indigenous Atlantic salmon parr for a depleted food resource (demonstrated by reductions in benthos samples) were forced to emigrate from the area in search of more readily available food. The numbers of brook trout in the single application block did not decline as markedly, but a decline was indicated, in that extensive sampling in mid-August yielded only a small sample for stomach content analysis. Samples of brook trout from the untreated control area were readily collected throughout the entire season.

Subsequent sampling at the end of the season (26 September) in both application blocks indicated large numbers of both salmon parr and

brook trout were present. All fish were easily collected and contained a variety of food organisms similar to the composition of benthos samples collected from the control during the same period, i.e., with a predominance of Trichoptera larvae.

Stomach content analysis of indigenous slimy sculpins did not indicate adverse effects of the permethrin applications on the feeding activity of this species.

PERMETHRIN-INDUCED KNOCKDOWN OF TERRESTRIAL ARTHROPODS

by

D. Kreutzweiser

Forest Pest Management Institute
Canadian Forestry Service
Environment Canada

The permethrin applications to the double block (in the treatment area described by Kingsbury and Kreutzweiser, p.112) resulted in a negligible to moderate increase in the knockdown of arboreal and flying invertebrates from both pin cherry blossoms and balsam fir foliage. The variety of invertebrates affected and the duration of the effects were similar in both cases. The number of terrestrial arthropods collected in post-spray samples peaked at 0 to 4.9 times higher than the pre-spray averages and consisted largely of adult Diptera, Hymenoptera, Lepidoptera, and Coleoptera. The pesticide-induced knockdown was almost immediate but did not persist beyond 48 h.

Supplementary samples collected on large drop sheets placed beneath single balsam fir trees on the day of spray application also indicated an immediate post-spray increase in arboreal and flying invertebrate knockdown. Average numbers of terrestrial arthropods collected in a two- or three-day post-application period in both the single and double blocks were substantially higher than the collections made during the same period in the control.

LETHALITY OF PERMETHRIN, CYPERMETHRIN, AND
FENVALERATE TO SALMON, LOBSTER, AND SHRIMP

by
D.W. McLeese, C.D. Metcalfe, and V. Zitko

Fisheries and Environmental Sciences
Fisheries and Oceans Canada

The results of this research indicate that permethrin, fenvalerate and cypermethrin are all lethal in low concentrations to salmon, lobsters and shrimp. As expected, lethality to invertebrates is more severe than to salmonids. For example, the 96-h LC50 of permethrin is 12 ppb for salmon, 0.7 ppb for lobster and 0.13 ppb for shrimp. Of the three pyrethroids studied fenvalerate is most toxic to salmon and cypermethrin is most toxic to invertebrates (e.g., the 96-h LC50 of cypermethrin to shrimp is 0.01 ppb). These pyrethroids have, however, low concentration factors (73, 7, and 200 for permethrin, cypermethrin and fenvalerate respectively over a four-day test period).

REFERENCE

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REGULATORY ASPECTS OF ENVIRONMENTAL MONITORING

by

K.W. Browne
Environment New Brunswick

The Pesticides Division, as part of the Plant Products and Quarantine Directorate, Food Production and Inspection Branch, Agriculture Canada, administers the federal Pest Control Products Act. The Division is composed of three sections: Evaluation, Compliance, and Technical Services.

Officers of the Evaluation Section review data submitted in support of applications for registration of new products and new uses for previously registered products, obtain the comments of expert advisors, and establish the status of products under the Pest Control Products Act.

Officers of the Compliance Section process applications for re-registration of previously registered products, and for registration of new products.

Officers of the Technical Services Section are responsible for the preparation, processing and dissemination of scientific, technical, regulatory and management information within the division.

The Pest Control Products Act is used to regulate products used for the control of pests and the organic functions (e.g., development or reproduction) of plants and animals. It deals, through regulation, with the registration, manufacture, labelling and sale of all control products within Canada.

A control product may have full or temporary registration status, or be exempted from registration for research purposes. If the applicant agrees to endeavour to produce scientific or technical information in relation to the use for which the control product is to be sold, a temporary registration for a period not to exceed one year may be issued. A temporary registration of a control product may also be approved for emergency control of infestations that are seriously detrimental to public health, domestic animals, natural resources or other concerns. The application of a control product in a research context can only be exempted from registration upon approval by the Director of the Pesticides Division, Plant Products and Quarantine Directorate of Aquaculture Canada.

In New Brunswick, no person shall apply a commercial or restricted pesticide (as defined in the Pest Control Products Act) to any area within the province unless he holds a permit issued by the provincial Minister of the Environment, with the following exceptions: A permit is not required for non-aerial application to land controlled by the applicator or to an area less than 5 ha where the application is for research purposes.

Applications for permits to conduct a spray program to control spruce budworm are forwarded by the provincial Minister of the Environment to the New Brunswick Pesticides Advisory Board for review. The Board holds special meetings, in addition to its regular meetings, to consider comments from the federal Atlantic Region Pesticide Advisory Committee and the Interdisciplinary Committee on Forestry Spraying. The Board then advises the Minister as to terms, conditions and restrictions that may be attached to the permit if such a permit is issued.

Given below is a list of conditions, reflecting environmental concerns, that are attached to permits issued for spray programs used to control spruce budworm:

1. That two applications only of the insecticide fenitrothion, in the requested formulation, be used at a maximum rate of 210 g a.i./ha or a single application at a maximum rate of 280 g a.i./ha. The latter is to be used only if weather conditions or insect development, or both, dictate that a single application is necessary for the successful completion of the project.
2. That aircraft spray nozzles must be shut off at a minimum distance of 400 m on any flight approach to open bodies of water and not reactivated until the spray aircraft has completely passed over the specified open bodies of water.
3. That aircraft spray nozzles delivering chemical pesticide must be shut off when within 400 m of the upwind side of those same open bodies of water.
4. In granting of spray permits, proximity of the operation to blueberry fields is taken into consideration. Generally, spraying is not conducted within four miles of blueberry fields.
5. That chemical pesticide be applied to those blocks adjacent to marine waters only when the wind direction is from the water towards the block.
6. That no chemical pesticide be applied within 400 m of designated ecological reserves.
7. That the applicator fully cooperate with agencies carrying out monitoring of the spray program.

Staff of the Toxic Substances Section of the New Brunswick Department of the Environment inspect permitted operations for compliance with these conditions.

Investigation of Mishaps

New Brunswick Environment has established a response procedure for aerial and ground mishaps which result in the accidental placement of pesticides in the environment. The contingency plan for mishaps involving insecticide formulations used in programs for the control of the spruce budworm is described below.

1. Response Procedure for the Applicator

(a) For all spills

1. Immediately wash the area where the pesticide has spilled onto the skin thoroughly with soap and water.
2. Remove all contaminated clothing and wash separately.
3. If anyone in the area feels ill, he should seek medical advice immediately.
4. Put on the recommended safety equipment and clean up the spill as quickly and safely as possible.
5. Decontaminate the affected area.
6. Complete the incident report form for pesticide spills and forward it to New Brunswick Environment.

(b) For major spills (ground spills greater than 130 L and all jettisoned loads or spills from aircraft)

1. Follow steps in Section A.
2. Contact ENVIRONMENTAL EMERGENCY NUMBER (Zenith 49-000).
3. Contact Ron Hicks, Public Health Branch, New Brunswick Department of Health (453-2397).
4. Contact Toxic Substances Section of the New Brunswick Department of the Environment (Zenith 08012).
5. Notify people living or working in the area that a spill of pesticide has occurred and advise them as to the safety measures they should follow.

2. Response Procedure for the Investigator

Upon notification, the Department of the Environment will evaluate the mishap and initiate the appropriate response procedure.

The response can vary from only a notation of the incident, to the immediate mounting of aerial or ground surveys. A damage evaluation and environmental sampling program may be associated with the latter. The extent of the response will be incident-specific and may require the participation of experts from various disciplines.

In all reported cases, the permit holder will be required to take the appropriate course of action to ensure minimal environmental disruption.

LIST OF CONTRIBUTORS AND THEIR ADDRESSES

Bailey, H.S.	Water Quality Branch, Inland Waters Directorate, Environment Canada, P.O. Box 861, Moncton, N.B. E1C 8N6
Baird, J.C.	Fish and Wildlife Branch, Department of Natural Resources, P.O. Box 6000, Fredericton, N.B. E3B 5H1
Belliveau, P.E.	(address as per H.S. Bailey)
Browne, K.W.	Environmental Services Branch, Environment New Brunswick, P.O. Box 6000, Fredericton, N.B. E3B 5H1
Brun, G.L.	(address as per H.S. Bailey)
Burridge, L.	Fisheries and Environmental Sciences Fisheries and Oceans Canada, Biological Station, St. Andrews, N.B. E0G 2X0
Busby, D.G.	Canadian Wildlife Service, Environment Canada, P.O. Box 400, Fredericton, N.B. E3B 4Z9
Chairman EMOFICO	Dr. D. Besner, Environmental Services Branch, Environment New Brunswick, P.O. Box 6000, Fredericton, N.B. E3B 5H1
Doe, K.G.	Environmental Protection Service, Environment Canada, 5th Floor, Queen Square, 45 Alderney Drive, Dartmouth, N.S. B2Y 2N6
Ecobichon, D.J.	Department of Pharmacology and Therapeutics, McGill University, Montreal, Quebec, H3A 2T5
Eidt, D.C.	Maritimes Forest Research Centre, Canadian Forestry Service, Environment Canada, P.O. Box 4000, Fredericton, N.B. E3B 5P7
Elner, J.K.	Fisheries and Environmental Sciences, Fisheries and Oceans Canada, Biological Station, St. Andrews, N.B. E0G 2X0 Present address: Fundy Isles Maine Enterprises, Ltd. St. Andrews, N.B. E0G 2X0
Ernst, W.R.	(address as per K.G. Doe)

Fraser, A.R.	Département de Chimie, Faculté des sciences et de génie, Université de Moncton, Moncton, N-B. E1A 3E9
Garritty, N.R.	(address as per D.G. Busby)
Holmes, S.	Forest Pest Management Institute Canadian Forest Service, Environment Canada, P.O. Box 490, Sault Ste. Marie, Ontario P6A 5M7
Horne, W.H.	(address as per K.G. Doe)
Julien, G.R.	(address as per K.G. Doe)
Ketella, E.C.	(address as per D.C. Eidt)
Kingsbury, P.	(address as per S. Holmes)
Kreutzweiser, D.	(address as per S. Holmes)
Levesque, D.	(address as per A.R. Fraser)
Li, M.F.	Fisheries and Environmental Sciences, Fisheries and Oceans Canada, Halifax Laboratory, P.O. Box 550, Halifax, N.S. B3J 2S7
Mallet, V.N.	(address as per A.R. Fraser)
Marryatt, V.	(address as per M.F. Li)
McLeese, D.W.	(address as per L. Burridge)
Metcalfe, C.D.	(address as per L. Burridge)
Millikin, R.L.	(address as per S. Holmes)
Parker, W.R.	(address as per K.G. Doe)
Pearce, P.A.	(address as per D.G. Busby)
Pelly, W.G.	(address as per K.G. Doe)
Planet, G.	1'Hôpital Georges Dumont, Moncton, N.B.
Redmond, M.	(address as per J.C. Baird)
Rona, G.	Lakeshore Diagnostic Services Inc., 175 Stillview Rd., Pointe-Claire, Quebec H9R 4S3

Secretary to EMOFICO	C. MacLaggan (address as per K. Browne)
Sergeant, D.B.	(address as per L. Burridge)
Sosiak, A.J.	Montreal Engineering Company, Limited, 500 Beaverbrook Court, Fredericton, N.B. E3B 5X4 Present address: Monenco Consultants, 900 One Palliser Square, 125 Ninth Avenue S.E., Calgary, Alberta T2G 0P6
Sundaram, K.M.S.	(address as per S. Holmes)
Szeto, S.	(address as per S. Holmes)
Townsend, D.R.	Washburn & Gillis Associates Ltd., 70 York Street, Fredericton, N.B. E3B 3N5
Trottier, B.	(address as per A.R. Fraser)
Varty, I.W.	(address as per D.C. Eidt)
Wildish, D.J.	(address as per L. Burridge)
Wood, G.W.	Agriculture Canada Research Station, Fredericton, N.B. E3B 4Z7
Zitko, V.	(address as per L. Burridge)
Zwicker, R.	(address as per M.F. Li)

List of Affiliations of
Individual EMOFICO Members

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Environment Canada

Atmospheric Environment Service

Canadian Forestry Service

Canadian Wildlife Service

Environmental Protection Service

Environmental Management Service (including Inland Waters Directorate)

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Maine Forest Service

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New Brunswick Department of Health (observer)

New Brunswick Department of Natural Resources

Newfoundland Department of the Environment

Newfoundland Department of Forests, Resources and Lands

Quebec Department of Energy and Resources

Research and Productivity Council

University of Maine

University of Moncton

University of New Brunswick

University of Toronto

Washburn & Gillis Associates Ltd.

Definitions, Descriptions of Various Insecticides,
and a Conversion Table (Separate Section)

A. Definitions

Basic Research: research for which the main objective is to define ecological or chemical processes basic to the interpretation of field monitoring.

Bioconcentration (or Bioaccumulation) Ratio: the concentration of a chemical in an animal's tissue divided by the concentration of that compound in the surrounding environment.

Field Monitoring: the determination of the spatial or temporal distribution of populations of an organism or of insecticide deposits or both, by sampling broadly enough to characterize a spray block or larger region of the province.

International Unit: a measure of the activity of microorganisms.

Pesticide Accountancy: the process of identifying the distribution and fate of pesticides and their breakdown products in the environment.

Sorbed: Taken up and held by absorption or adsorption.

B. Insecticides

Acephate (O,S-dimethyl acetylphosphoramidothioate) is an organophosphate insecticide sold under the names Orthene^R, Ortran^R, Ortril^R, and Toronado^R.

Aminocarb ((4-dimethylaminophenyl-3-methyl-phenyl)-N-methylcarbamate) is a carbamate insecticide sold under the names Bay -44646^R, Matacil^R, and Metacil^R. The conventional Matacil 1.8D formulation which has been used in the past in New Brunswick contains the adjuvents nonylphenol and a diluent oil. The 1.8F formulation applied experimentally in New Brunswick does not contain nonylphenol.

Bacillus thuringiensis is a gram positive bacterium. Preparations of this insecticide are sold under the names Bactospeine^R, Dipel^R, and Thuricide^R.

Carbaryl (1-naphthyl methylcarbamate) is a carbamate insecticide sold under the names Sevin^R and 7744. Formulations referred to in the text are Sevin-4-Oil and Sevin-2-Oil which contain Sevin and oil in a 4:1 and 2:1 ratio respectively.

Chlorpyrifos-methyl (0, 0-dimethyl 0-(3,5,6-trichloro-2-pyridyl) phosphorothioate) is an organophosphate insecticide sold under the names Dowco 214^R, Reldan^R, and Zertell^R.

Dimethoate (0, 0-dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate) is an organophosphate insecticide sold under the names Cygon^R, PERFEKTHION^R, Rogor^R, Roxion^R, AC 12880, ENT 24650, NC 262, and L 395.

Fenitrothion (0,0-dimethyl-0-(3-methyl-4-nitrophenol) phosphorothioate) is an organophosphate insecticide sold under the names Sumithion^R, Folithion^R, Accothion^R, Agrothion^R, Novathion^R, Nuvanol^R, Methathion^R, Methylnitropos^R, and Danathion^R.

Permethrin ((3-phenoxyphenol)-methyl (+ or -) cis-trans-3-(2,2-dichloroethenyl)-2,2) dimethylcyclopropane-carboxylate) is a synthetic pyrethroid compound sold under the names Eksin^R, Ambush^R, Ectibon^R, PP-557, Kafil^R, Pounce^R, and FMC-33297.

C. Conversions

B.I.U. = Billion International Units

g 1 gram = 0.032 ounces

µg = 1 microgram = 1 gram/1,000,000

h = hours

ha 1 hectare = 2.47 acres

km 1 kilometre = 0.62 miles

L 1 litre = 0.22 gallons (Imperial)

µl 1 microlitre = 1 litre/1,000,000

min = minutes

ppb = parts per billion (approximately = µg/L in water)

ppm = parts per million (approximately = mg/L in water)

ACKNOWLEDGEMENTS

I wish especially to thank the members of the steering committee overseeing the preparation of the report, Dr. D.C. Eidt, Mr. P.A. Pearce, and Dr. D. Besner, for their encouragement and constructive comments. I am also grateful to Ms. Cathy MacLaggan, Secretary to EMOFICO, whose efforts greatly facilitated preparation of the report.

Thanks are also due to representatives of provincial, federal and state departments and agencies who provided me with background information which was used in the preparation of the overview summary section and to Mrs. Judy Hill for typing the various drafts of the report.

Finally, I would like to thank the members of EMOFICO who prepared summaries or introductory sections or both for this report.